INSTRUCTION
MANUAL
FOR·····

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Type 136

Precision Test Receiver

136 Rev A

AIRBORNE INSTRUMENTS LABORATORY A DIVISION OF CUTLER-HAMMER
DEER PARK, LONG ISLAND, NEW YORK 11729

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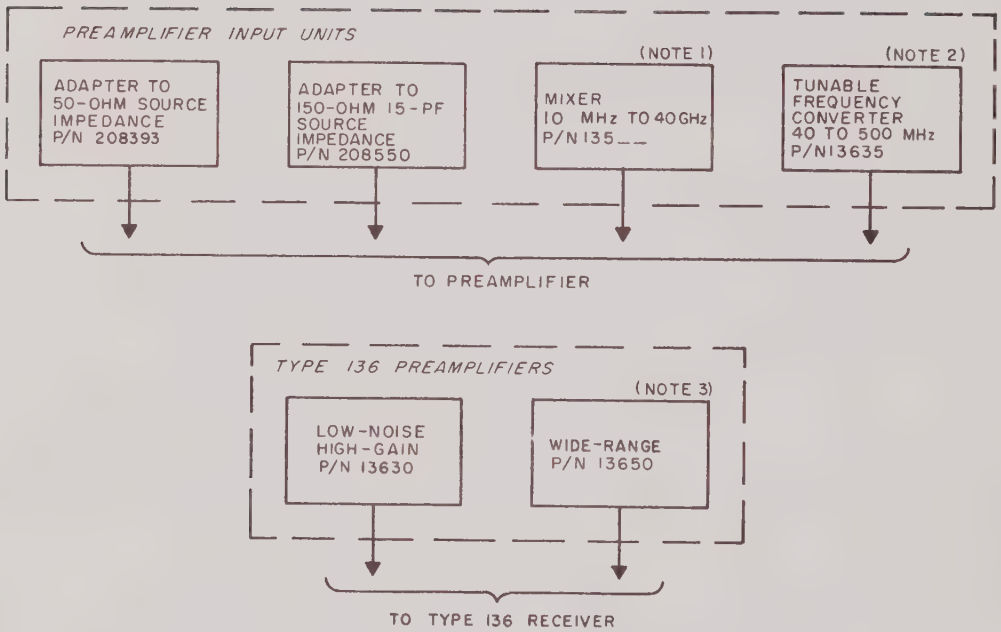
SECTION 1. INTRODUCTION

The AIL Type 136 Precision Test Receiver (Figure 1) is a laboratory test instrument whose primary function is to accurately measure signal-level changes. Among its many applications are:

1. Calibration of RF and IF attenuators and directional couplers,
2. Calibration of signal-generator output attenuators,
3. Measurement of noise figure,
4. Measurement of gain and linearity characteristics of RF and IF amplifiers,
5. Measurement of transmission and selectivity characteristics of RF and IF components (isolators, tuners, power dividers, etc.).

Accessory items (Figure 2) are available for use with the Type 136 Receiver for a variety of applications. These include preamplifiers, preamplifier impedance adapters, mixers, and a frequency converter.

FIGURE 1. TYPE 136 PRECISION TEST RECEIVER, P/N 13610


PREAMPLIFIER INPUT UNITS
ADAPTER TO 50-OHM SOURCE IMPEDANCE P/N 208393
ADAPTER TO 150-OHM 15-PF SOURCE IMPEDANCE P/N 208550
(NOTE 1)
MIXER 10 MHz TO 40GHz P/N 135__
(NOTE 2)
TUNABLE FREQUENCY CONVERTER 40 TO 500 MHz P/N13635
TO PREAMPLIFIER
TYPE 136 PREAMPLIFIERS
(NOTE 3)
LOW-NOISE HIGH-GAIN P/N 13630
WIDE-RANGE P/N 13650
TO TYPE 136 RECEIVER

NOTES

1. SEE APPENDIX CI OR CATALOG ON MIXERS AND AMPLIFIERS
2. SEE APPENDIX D FOR APPLICATIONS OF FREQUENCY CONVERTER
3. SEE APPENDIX E FOR APPLICATIONS OF PREAMPLIFIER

FIGURE 2. ACCESSORIES AND OPTIONS

SECTION 2. SPECIFICATIONS

2.1 RECEIVER, P/N 13610

Center frequency	30 MHz
3-dB bandwidth	1 MHz
Noise figure	8.5 dB (max)
Input impedance	50 ohms nominal
Full-scale sensitivity (note 1)	-90 dBm
Overall IF and video voltage gain	100 dB
Video output	0.5 volt (100-ohm load) max
Rise and fall time	1.5 μsec (max)
IF output	100 mv (50-ohm load) min
IF input to IF output gain	83 dB min
Gain control range	50 dB min
Attenuator:	
Center frequency	30 MHz
Minimum insertion loss	18 dB nominal
Maximum input power	1 watt
Input impedance	50 ohms nominal
Output impedance	50 ohms nominal
Range, incremental	100 dB min
Error, max (dB)	0.005/10 + 0.03 + 0.03 (note 2) $\leq <$ 0.03 (note 3)
Resolution	0.01 dB/division
Measurement range:	
IF	100 dB
RF	75 dB
Scale resolution	Normal: 0.1 dB/division (note 4) Expanded: 0.01 dB/division (note 5)
Power required	115/230 VAC ±10 percent, 50 to 400 Hz, 20 watts
Size (Figure 3)	19-13/16 by 9-7/8 by 17-3/4 inches
Weight	32 pounds

Notes:

1. Available signal power at Postamp input, which will cause the meter to read full-scale or greater when the METER function switch is set to DETECTOR, NORM.
2. This error may occur when the attenuator reference is set for a digital dial reading of 0.00.
3. When the attenuator reference is set for a digital dial reading of 10.00 or larger, the error is negligible.
4. Change in input-signal level required for a change of a single division in meter indication when operating near full scale.
5. Sinusoidal signals only; resolution is 0.02 dB per division when input consists of noise only.

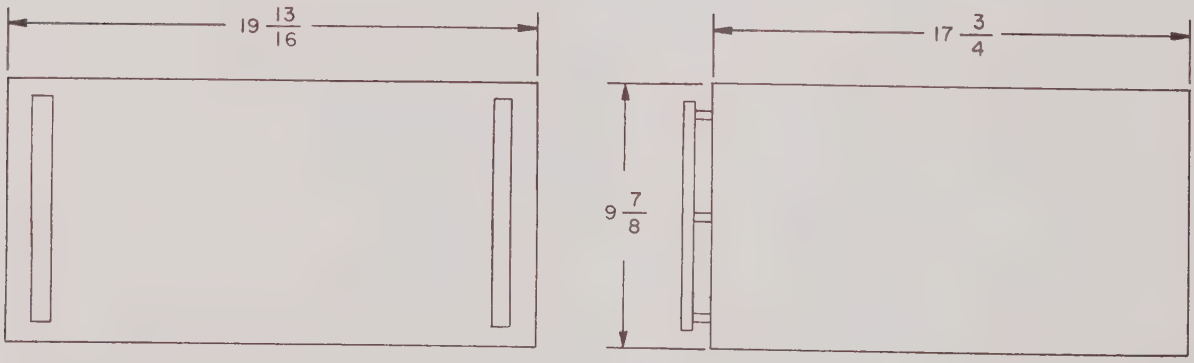


FIGURE 3. OUTLINE DRAWING OF P/N 13610

2.2 LOW-NOISE PREAMPLIFIER, P/N 13630

Center frequency	30 MHz
IF noise figure	2.5 dB typ
Gain	43 dB min
Bandwidth	3 MHz min
Linear output power	-10 dBm for 0.1-dB compression
Power required	40 VDC at 58 mA or 15 VDC at 47 mA
Size (excluding mixers, adapters, and connectors)	5-1/4 by 3-1/4 by 1-1/2 inches
Weight	11 ounces

2.3 WIDE RANGE PREAMPLIFIER, P/N 13650

Center frequency	30 MHz
IF noise figure	12 dB
Gain	30 dB
Bandwidth	2 MHz
Maximum output power	+28 dBm (50-ohm load)
Maximum linear output power	+15 dBm for 0.1-dB compression
Power required	40 VDC at 135 mA
Size (excluding mixers, adapters, and connectors)	8-1/2 by 3-1/4 by 1-1/2 inches
Weight	16 ounces

2.4 TUNABLE FREQUENCY CONVERTER, P/N 13635

Frequency range	40 to 500 MHz
Conversion loss	
(40 to 150 MHz)	6 dB
(150 to 500 MHz)	26 dB
Source impedance	50 ohms
Load impedance	Plugs into Type 136 preamplifiers
Power required	Obtained from Type 136 preamplifiers
Size	6 by 3-1/2 by 1-1/2 inches
Weight	8 ounces

2.5 50-OHM IMPEDANCE ADAPTER, P/N 208393

IF bandwidth	30-100 MHz
Output impedance (nominal)	175 ohms in parallel with 15 pf
Source impedance	50 ohms
Input connector	BNC
Output connector	Pin
Size	3-1/4 by 1-1/2 by 1-1/2
Weight	8 ounces

2.6 150-OHM IMPEDANCE ADAPTER, P/N 208550

IF center frequency	30 MHz
Output impedance (nominal)	135 ohms in parallel with 15 pf
Source impedance	50 ohms
Input connector	BNC
Output connector	Pin
Size	3-1/4 by 1-1/2 by 1-1/2
Weight	8 ounces

SECTION 3. OPERATING CONTROLS AND INDICATORS

Figure 4 shows the front-panel controls, indicators, and connectors for the 13610.

Reference Number	Nomenclature	Function
1	Meter	Indicates second detector and crystal currents
2	ATTENUATION DB indicator	Indicates attenuator setting
3	Precision Attenuator knob	Controls attenuation setting continuously from 0 to 100 dB
4	INPUT 50 ohms connector	Provides access to attenuator input

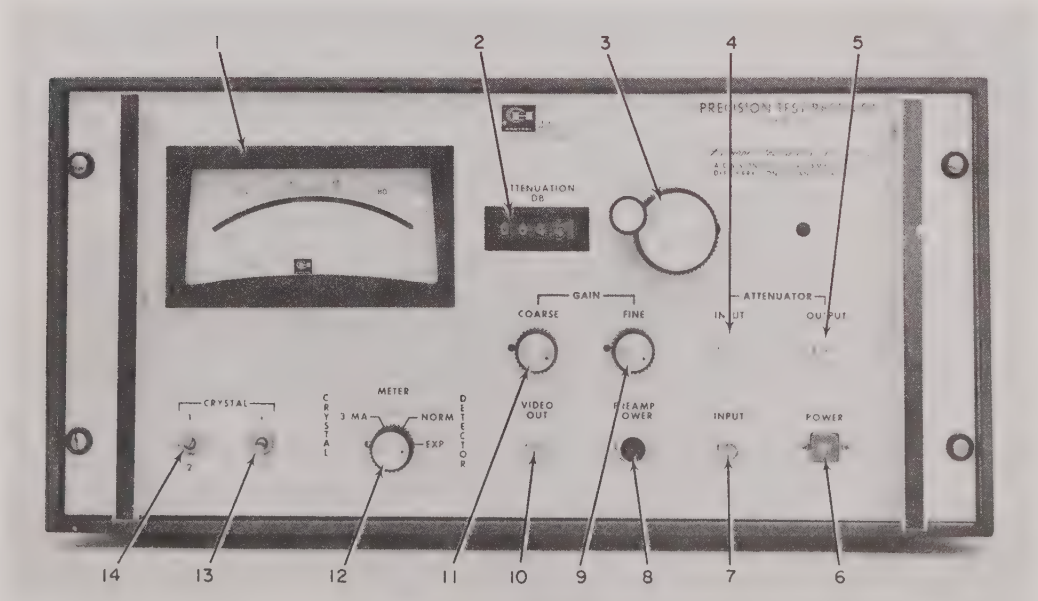


FIGURE 4. RECEIVER P/N 13610, CONTROLS AND INDICATORS

Reference Number	Nomenclature	Function
5	OUTPUT 50 ohms connector	Provides access from attenuator output
6	POWER switch - lamp	Controls primary power. Lights when primary power is on
7	INPUT connector	Provides access to postamplifier input
8	PREAMP POWER connector	Provides power for external preamplifier and access to crystal current meter
9	GAIN, FINE control	Provides vernier control of postamplifier gain
10	VIDEO OUT connector	Provides access to video amplifier output
11	GAIN, COARSE control	Provides wide-range control of postamplifier gain
12	METER switch	Selects function of panel meter: CRYSTAL, 3 MA - crystal current monitor DETECTOR, NORM - detector current normal sensitivity DETECTOR, EXP - detector current expanded scale
13	CRYSTAL +, - switch	Selects meter polarity for monitoring crystal current
14	CRYSTAL 1, 2 switch	Selects crystal to be monitored

SECTION 4. OPERATING INSTRUCTIONS

4.1 INTRODUCTION

The series-substitution method provides a simple, highly accurate method of measuring signal level changes or attenuation. It depends on the strict in-line substitution of attenuation for a changed signal level to reproduce an original reference level. The general procedure is as follows:

a. A reference signal level is established at the input to the receiver system.

b. The indicated signal level is noted by monitoring the postamplifier detector current. It is not necessary to know the absolute signal level.

c. The input level is changed by: (1) inserting a device having an unknown attenuation into the system (Figure 5), or (2) changing the input signal level (either CW or noise).

d. An accurate, continuously variable attenuator in series with the input is then varied until the detector current monitor returns to the original indication. The attenuator variation is then equal to the signal level change.

4.2 SPECIAL PROCEDURES

The variable attenuator is a precision device having a mechanical drive and readout system that includes an antibacklash feature. However, to eliminate any small amount of residual backlash in the drive mechanism, it is good practice to approach all readings using the same direction of rotation of the control knob. Counterclockwise rotation is usually found to be more convenient. This would mean that in a normal sequence of two readings, the knob would be turned continuously in one direction, counterclockwise. In approaching

any reading from the high side, as in setting the initial reading, the knob should be turned beyond the desired reading (a few tenths of a dB) and then rotated counterclockwise to the desired position.

All measurements described in this manual are made with the METER switch set to DETECTOR EXP. Extremely small signal-level changes (0.01 dB per meter division for sinusoidal signals) can thus be resolved. If this precision is not required, the switch can be set to DETECTOR NORM. The system resolution will then be about 0.1 dB for a single meter division when operating near full scale.

4.3 IF ATTENUATION MEASUREMENTS (30 MHz)

4.3.1 MEASUREMENT THEORY

The Type 136 Receiver can be used to make attenuation measurements of 100 dB at 30 MHz. The arrangement of the measurement equipment is shown in Figure 5. The wide-range preamplifier is used to provide a high-level input signal. When operated with an input signal of at least 1 mw, it will provide an output of approximately 28 dBm. Under these conditions, the output stage of the preamplifier saturates and thereby improves the amplitude stability of the signal source.

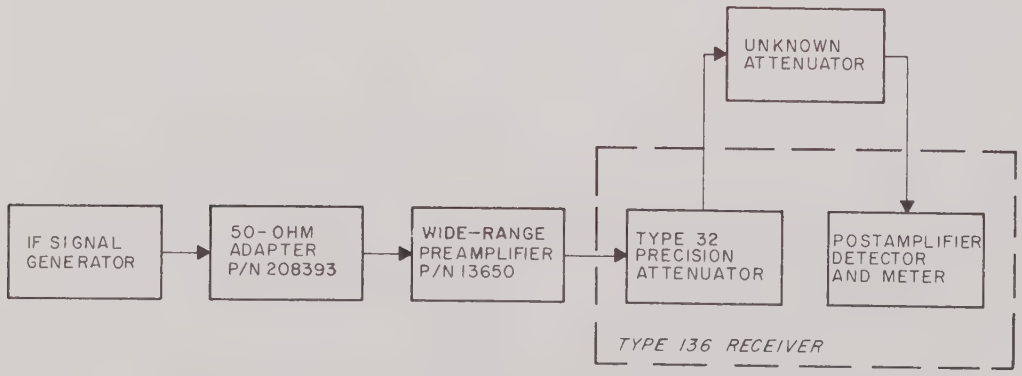


FIGURE 5. IF ATTENUATION MEASUREMENT SETUP

An alternative arrangement of this equipment which can be used to advantage in certain measurements is shown in Figure 6. The wide-range preamplifier is not used, and the attenuation measurement range is limited by the power available from the signal generator. With an available power of 0 dBm, the attenuation measurement range is about 85 dB.

Typically, a measurement is made as follows. The precision attenuator is set to a convenient reference (0 dB), and the output level of the signal generator is set to 0 dBM. After the receiver gain is adjusted to obtain a convenient reference reading on the meter, the unknown is removed and the precision attenuator is connected directly to the signal source. The precision attenuator is increased until the meter returns to the original reference indication. The unknown attenuation is read directly (in dB) on the precision attenuator indicator.

4.3.2 MEASUREMENT PROCEDURE

a. Set up equipment as shown in either Figure 5 or 6, depending on the conditions discussed above.

b. Set the PRECISION ATTENUATOR to 0 dB.

c. Set the signal-generator output level to 0 dBm.

d. Set the METER switch to DETECTOR NORM.

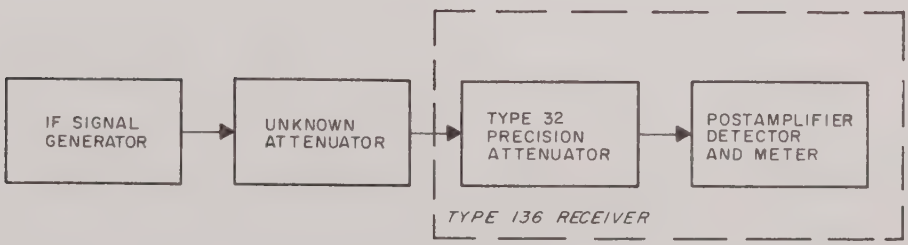


FIGURE 6. SIMPLIFIED IF ATTENUATION MEASUREMENT SETUP

e. Adjust the GAIN controls for a full-scale indication on the receiver front-panel meter. If necessary, readjust the signal-generator output level.

f. Set the METER switch to DETECTOR EXP.

g. Adjust the FINE GAIN control for a convenient reference level indication on the meter.

h. Remove the unknown attenuator.

i. Increase the PRECISION ATTENUATOR setting until the meter returns to the reference indication that was set in step g.

j. Read the unknown attenuation on the ATTENUATION DB readout.

4.4 RF ATTENUATION MEASUREMENTS

4.4.1 MEASUREMENT THEORY

The measurement of RF attenuation requires the use of a mixer to convert the signal to the 30-MHz center frequency of the receiver. This can be conveniently performed by mating either one of the Type 136 preamplifiers to one of the AIL Type 135 mixers (Appendix C) or by attaching an impedance adapter to one of the Type 136 preamplifiers and using any standard mixer having a single-ended IF output of the proper impedance. Figure 7 shows the general setup for measuring RF attenuation.

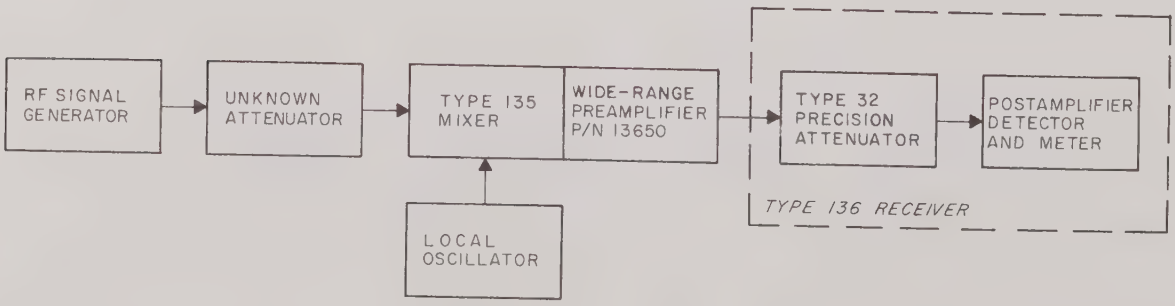


FIGURE 7. RF ATTENUATION MEASUREMENT SETUP

The measurement procedure is basically identical with that for IF attenuation measurement. As shown in Figure 7, the unknown is inserted between the signal source and the input of the mixer. The precision attenuator is between the preamplifier output and the postamplifier IF input.

This arrangement sets a further limitation on the measurement range and accuracy. The mixer-preamplifier combination must remain absolutely linear over the full variation of input-signal level. In this measurement, the linear dynamic range of the mixer-preamplifier combination determines the attenuation measurement range.

The linear dynamic range of any receiver is limited at low signal levels by the system noise level. Using a Type 135 Mixer mated to a Type 136 Wide Range Preamplifier (P/N 13650) results in a system noise level that limits the minimum useful signal level to approximately -80 dBm.

The upper limit of the linear range of the system is determined by the signal-handling capability of the mixer. For a maximum error of 0.2 dB due to this limitation, the input signal level must not exceed a level of 8 dB below the power delivered to the crystals by the local oscillator. Noise matching and conversion efficiency considerations generally require an input to the crystals of a balanced mixer of about 2 mw. The corresponding upper limit of the linear signal range is approximately -5 dBm.

It can be seen that, if maximum accuracy is to be maintained over the full measurement range of the instrument, the input signal level to the mixer must remain within the limit of -80 to -5 dBm. This allows a maximum single-step measurement of 75 dB. Figure 8 shows the error in a typical RF attenuation measurement setup. This characteristic is shown as a guide only. To obtain the maximum accuracy in any system, the user should measure this characteristic of his own equipment (Appendix A).

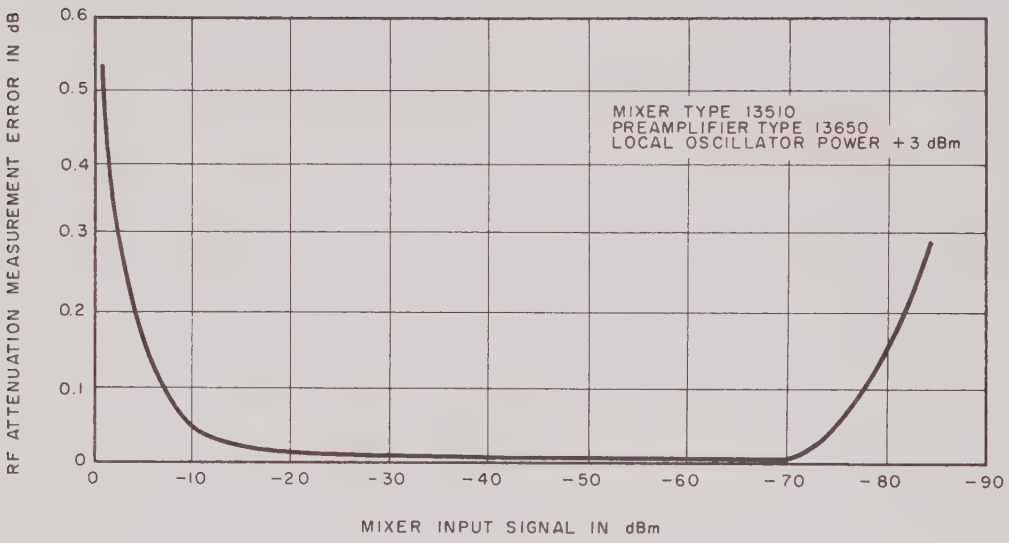


FIGURE 8. RF ATTENUATION MEASUREMENT ERROR AS A FUNCTION OF SIGNAL LEVEL

The range of the measurement setup can be extended to 85 dB by using the low-noise preamplifier. This preamplifier, when used with a Type 135 mixer, is useful over the RF signal range from -55 to -90 dBm.

Another method that can be used to increase the RF attenuation measurement range is partial RF substitution. The procedure is described under paragraph 4.4.3. Basically, the difference between this method and the single-step method described above is that a fixed RF attenuator of known insertion loss is inserted in place of the unknown attenuator for the second reading. This attenuator permits the use of a higher input signal from the signal generator. The increase in attenuation measurement range is limited to the increase in available power above the limit of -5 dBm described previously.

4.4.2 MEASUREMENT PROCEDURE (SINGLE STEP)

a. Set up the equipment as shown in Figure 8.

b. Set the signal generator to the desired operating frequency.

c. Adjust the signal-generator output level so that the mixer input is about -60 dBm.

d. Set the PRECISION ATTENUATOR to zero.

e. Set the local-oscillator frequency 30 MHz higher than the signal-generator frequency.

f. Set the METER switch to CRYSTAL 3 MA.

g. Adjust the local-oscillator output for the rated crystal current (1 to 2 mA for the Type 135 mixers) as indicated by the front-panel meter. It may be necessary to operate the CRYSTAL 1, 2, and +, - switches to obtain up-scale readings.

h. Set the METER switch to DETECTOR NORM.

i. Carefully adjust the local-oscillator frequency for a peak indication on the meter. Adjust the GAIN controls, if necessary, to maintain an on-scale indication.

j. Set the signal generator output level in accordance with the criteria established in paragraph 4.4.1.

k. Adjust the GAIN controls for a full-scale indication on the meter.

l. Set the METER switch to DETECTOR EXP.

m. Adjust the FINE GAIN control for a convenient reference setting on the meter.

n. Remove the unknown attenuator and connect the signal-generator output directly to the mixer input.

o. Adjust the PRECISION ATTENUATOR until the detector meter is at the reference set in step n.

p. Read the unknown attenuation directly from the ATTENUATION DB readout.

4.4.3 MEASUREMENT PROCEDURE (PARTIAL RF SUBSTITUTION)

a. Set up the equipment as shown in Figure 8.

b. Set the signal generator to the desired operating frequency.

c. Adjust the signal-generator output level so that the mixer input is about -60 dBm.

d. Set the PRECISION ATTENUATOR to zero.

e. Set the local-oscillator frequency 30 MHz higher than the signal-generator frequency.

f. Set the METER switch to CRYSTAL 3 MA.

g. Adjust the local-oscillator output for the rated crystal current (1 to 2 mA for the Type 135 mixers) as indicated by the front-panel meter. It may be necessary to operate the CRYSTAL 1, 2, and +, - switches to obtain up-scale readings.

h. Set the METER switch to DETECTOR NORM.

i. Carefully adjust the local-oscillator frequency for a peak indication on the meter. Adjust the GAIN controls, if necessary, to maintain an on-scale indication.

j. Insert a fixed, calibrated RF attenuator in place of the unknown attenuator.

k. Set the signal generator output level to maintain the signal level at the input to the mixer within the limits described in paragraph 4.3.1, with either the calibrated attenuator or the unknown attenuator in place.

l. Insert the unknown attenuator in place of the calibrated attenuator.

m. Adjust the GAIN controls for a full-scale indication on the meter.

n. Set the METER switch to DETECTOR EXP.

o. Adjust the FINE GAIN control for a convenient reference setting on the meter.

p. Replace the unknown attenuator with the calibrated attenuator.

q. Adjust the PRECISION ATTENUATOR until the detector meter is at the reference set in step p.

r. Read the ATTENUATION DB readout. The unknown attenuator is equal to the sum of this reading and the attenuation (dB) of the calibrated attenuator.

4.5 GAIN MEASUREMENTS

Gain measurements at IF or RF are made in the same manner as attenuation measurements. For convenience the reference indication is set and noted before inserting the unknown into the circuit. All precautions regarding signal levels should also be observed in these measurements.

4.6 ACCURACY OF ATTENUATION MEASUREMENTS

The procedure described above for the measurement of attenuation illustrate the manner in which the equipment is arranged and the sequence of operation. Certain techniques common to each of these measurements should be adopted to avoid errors resulting from impedance mismatch, nonlinearity of vital components, and other imperfections in the test equipment. Sufficient information is contained in Appendix A to enable the operator to detect these errors and to take corrective action.

4.7 THEORY OF NOISE-FIGURE MEASUREMENT

The Type 136 Receiver can be used to make very accurate noise-figure measurements by means of the manual Y-factor method. In this measurement, the change in the noise output level of the device under test is noted when a known change is made in the noise power available from the input termination. The desired changed in available noise power (or effective source temperature) is accomplished by means of a variety of noise generators. A complete list of suitable noise generators is contained in Appendix C. The formulas used in calculating the measured noise figure and their derivations are contained in Appendix B.

4.8 PRELIMINARY ADJUSTMENTS FOR NOISE-FIGURE MEASUREMENTS

4.8.1 RF AMPLIFIER

For purposes of this test procedure, any amplifier having the same input and output frequencies is defined as an RF amplifier. The arrangement of the test equipment required for noise-figure measurements is shown in Figure 9. The AIL series of mixers designated as Type 135 covers the frequency range from 10 MHz to 40 GHz. They are designed to be secured interchangeably to the front end of the amplifier. Either the 13630 or 13650 preamplifier should be used. The choice of amplifier depends upon the gain and noise figure of the RF amplifier. The wide-range preamplifier should be used when the RF amplifier gain is more than about 25 dB. The proper mixer for the desired frequency range can be selected from the list in Appendix C. In addition, an amplifier operating at 30 MHz can be tested by using the 50-ohm adapter (AIL Part No. 208393) in place of a mixer.

The initial adjustments for this type of measurement are:

a. Set the local-oscillator frequency 30 MHz above or below the desired operating frequency (the local oscillator can be adjusted for maximum detector current).

b. Set the METER switch to CRYSTAL 3 MA.

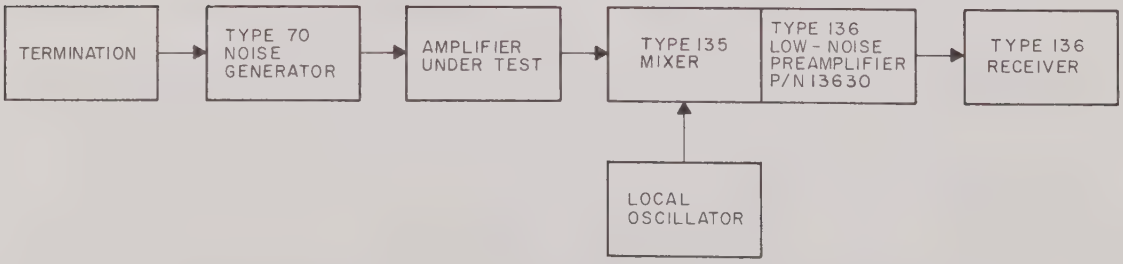


FIGURE 9. SETUP FOR MEASURING NOISE FIGURE OF RF AMPLIFIER

c. Adjust the local-oscillator output level for rated crystal current on both crystals. It will be necessary to operate the CRYSTAL selector (1 or 2) and polarity (- or +) switches to obtain an up-scale reading and determine whether both crystals are operating.

d. Set the METER switch to DETECTOR NORM.

e. Set the PRECISION ATTENUATOR to zero.

4.8.2 SUPERHETERODYNE RECEIVER

A superheterodyne receiver is an amplifier in which a part of the total gain is accomplished at an intermediate frequency that is different from the signal input frequency. When an output at this intermediate frequency is available from the receiver, a measurement of the noise figure of the receiver can be made using the test equipment shown in Figure 10.

The AIL frequency converter (P/N 13635) covers the range from 40 to 150 MHz. When the IF of the receiver under test is 30 MHz, the converter is replaced by a simple impedance-matching device (P/N 208393) that provides a 50-ohm input impedance for the preamplifier. Both the converter and the preamplifier can be omitted if the receiver under test has sufficient gain (45 dB minimum) from the RF input to the 30 MHz output.

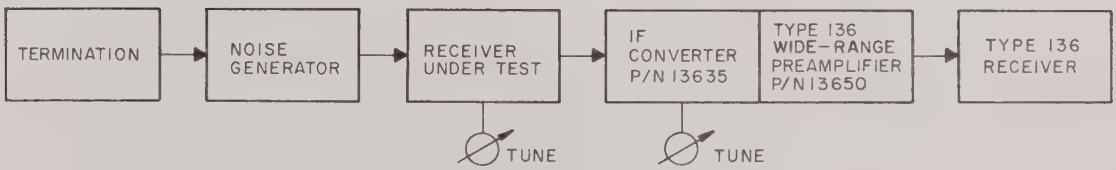


FIGURE 10. NOISE-FIGURE MEASUREMENT SETUP FOR SUPERHETERODYNE RECEIVER

The initial adjustments for this measurement are:

a. Tune the receiver to the desired operating frequency.

b. Tune the IF converter to the output frequency of the receiver under test; adjust for maximum output.

c. Set the METER function switch to NORM.

d. Set the PRECISION ATTENUATOR to zero.

4.8.3 MIXER

A mixer has an output at an intermediate frequency that differs from the signal input frequency. However, the usual microwave mixer has an overall power loss. Noise-figure measurement of such a device must take into account the noise figure of the amplifier following the mixer. Furthermore, this amplifier must be designed to operate from the source impedance presented by the mixer or, at least, its noise figure must be known when operating from this particular source impedance.

The 150-ohm impedance adapter is suitable for use with most mixers employing two microwave diodes. The manner in which these impedance and other factors are taken into account in the measurement of noise figure is covered in Appendix B. The general arrangement of the test equipment is shown in Figure 11.

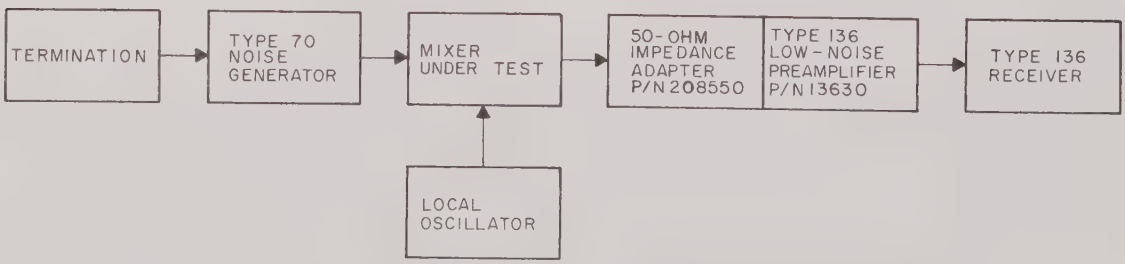


FIGURE 11. SETUP FOR NOISE-FIGURE MEASUREMENT OF A MIXER

The following initial adjustments should be made:

a. Set the local-oscillator frequency 30 MHz above or below the desired operating frequency (the local oscillator can be adjusted for maximum detector current).

b. Adjust the local-oscillator output level in accordance with the requirements of the mixer. In certain mixers having provisions for monitoring crystal current through the IF output connection, this current can be measured on the receiver panel meter by setting the METER function switch to CRYSTAL 3 MA. It will be necessary to select the proper positions of the CRYSTAL selector (1 or 2) and polarity (- or +) switches to obtain a meter reading.

c. Set the METER function switch to NORM.

d. Set the PRECISION ATTENUATOR to zero.

4.9 NOISE-FIGURE MEASUREMENT PROCEDURES

The procedure for measuring noise figure will vary slightly, depending on the type of noise generator used: temperature-limited diode, gas-discharge, or hot-cold standard noise generator.

4.9.1 TEMPERATURE-LIMITED DIODE (Y-FACTOR METHOD)

A thermionic diode, operated in the temperature-limited region of its V-I characteristic and properly terminated, makes an accurate noise generator in the IF-UHF region. The AIL Type 07006 is such a device. The termination and coupling network are internal to the noise source. A noise-diode power supply, such as the AIL Type 07112, is also required for this measurement. A power supply of this type is also an integral part of the Type 74A Automatic Noise Figure Indicator. The measurement procedure is as follows:

a. Set up the equipment in accordance with paragraphs 4.8.1, 4.8.2, or 4.8.3, and perform whatever initial adjustments are required (local-oscillator settings, etc.).

b. Connect the noise-generator output to the input of the system under test, and connect the noise-generator power cable to its power supply.

c. Check that the METER switch is set to DETECTOR NORM and the PRECISION ATTENUATOR set to zero dB.

d. With the noise-diode power supply turned off, adjust the GAIN controls for a full-scale reading on the meter.

e. Set the METER switch to DETECTOR EXP.

f. Adjust the GAIN controls for a convenient reference reading.

g. Energize the noise-diode power supply.

h. Place the power supply RANGE switch to the 0-16 dB position.

i. Adjust the diode current for a reading of 15.3 dB on the power supply meter (33.8 mA, if the power supply meter reads diode plate current directly).

j. Increase the setting of the PRECISION ATTENUATOR until the receiver meter returns to the reference setting of step f.

k. The new attenuator reading is the Y factor.

l. Using the 15.3-dB curve in Figure 12, read the system noise figure corresponding to the measured Y factor, or use the AIL Noise Figure Slide Rule.

4.9.2 TEMPERATURE-LIMITED DIODE (3-dB METHOD)

The ease with which the noise output of the Type 7006 Noise Diode can be varied provides a second, convenient method of measuring noise figure. This is called the 3-dB or Constant Y-Factor Method.

a. Set up the equipment in accordance with paragraphs 4.8.1, 4.8.2, or 4.8.3, and perform whatever initial adjustments are required (local-oscillator settings, etc.).

b. Connect the noise-generator output to the input of the system under test, and connect the noise-generator power cable to its power supply.

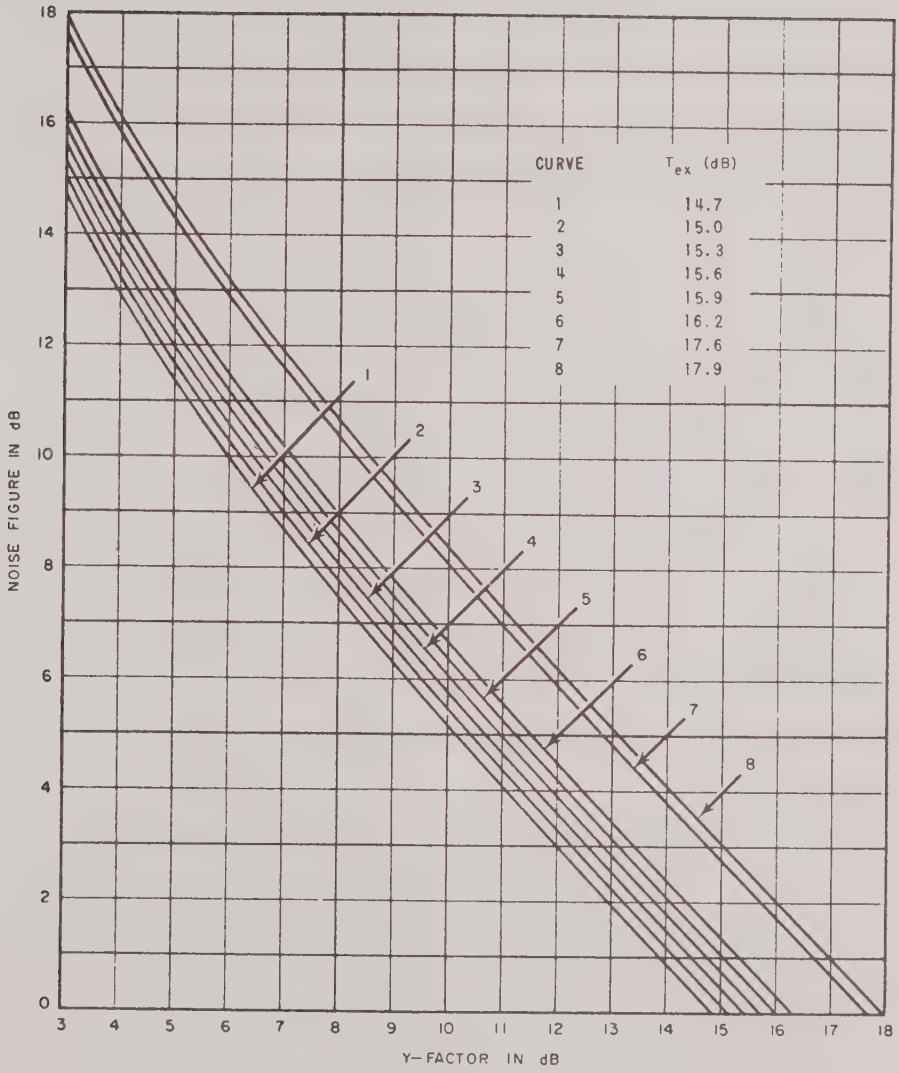


FIGURE 12. NOISE FIGURE VS Y-FACTOR FOR VARIOUS DISCHARGE GENERATORS

c. Check that the METER switch is set to DETECTOR NORM and the PRECISION ATTENUATOR set to zero dB.

d. With the noise-diode power supply turned off, adjust the GAIN controls for a full-scale reading on the meter.

e. Set the METER switch to DETECTOR EXP.

f. Adjust the GAIN controls for a convenient reference reading.

g. Readjust the PRECISION ATTENUATOR for a reading of exactly 3 db.

h. Energize the noise-diode power supply. Adjust the noise-diode current until the receiver front-panel meter again indicates the reference level set in step f.

i. If the Type 07112 Noise Diode Power Supply is used, read the system noise figure directly from its front-panel meter.

j. Alternatively, if the noise-diode plate current is read directly (as when the Type 74A Automatic Noise Figure Indicator is used as a power supply), the system noise figure (in dB) can be calculated from the following expression:

$$F = 10 \log 20 IR$$

where

I = noise diode DC plate current in amperes,

R = terminating resistance in ohms.

In the Type 7006 Noise Diode, R is equal to 50 ohms. Consequently,

$$F = 10 \log I \text{ (mA)}$$

4.9.3 GAS-DISCHARGE NOISE GENERATOR

Gas-discharge noise generators are generally used above 200 MHz. AIL Type 70 Noise Generators (Appendix C) cover the range of 200 MHz to 40 GHz. Two coaxial types (7010 and 7012) operate from 200 MHz to 5 GHz, and a series of waveguide types are used to cover the range from 2.6 to 40 GHz.

Gas-discharge noise generators require a special power supply that provides an ignition pulse many times higher than the operating potential as well as the sustaining voltage and current. The AIL Type 7111 Noise Generator Power Supply serves this purpose in addition to providing noise generator current monitoring and control. The Type 74A Automatic Noise Figure Indicator also contains a suitable gas-discharge noise-generator power supply.

Gas-discharge generators are provided without terminations; however, internally mounted terminations (listed in Appendix C) are available from AIL for the waveguide units. Standard commercial coaxial RF terminations are usually suitable for the coaxial generators.

The Y-factor method is the most popular means of making noise-figure measurements with gas-discharge noise generators. The procedure described below is essentially the same as that used with noise diodes (paragraph 4.9.1). The correct operating current is listed in the handbook of operating instructions for the particular generator.

a. Connect the noise-generator output to the input of the system under test. Connect a termination to the opposite end, and connect the power cables from the power supply. Make whatever initial adjustments are required (local-oscillator settings, etc.).

b. Check that the PRECISION ATTENUATOR is set to zero dB.

c. Set the METER switch to DETECTOR NORM.

d. Adjust the GAIN controls for a full-scale meter indication.

e. Set the METER switch to DETECTOR EXP.

f. Adjust the GAIN controls for a convenient reference reading.

g. Ignite the noise lamp by operating the noise-generator power supply. Set the current adjust control for the proper operating current (refer to the noise-generator handbook).

h. Readjust the PRECISION ATTENUATOR until the meter returns to the reference set in step f.

i. The new setting of the PRECISION ATTENUATOR is the Y factor.

j. Refer to Figure 12. Using the T_{ex} curve closest to that given in the noise-generator handbook, read the system noise figure corresponding to the measured Y factor.

4.9.4 HOT-COLD STANDARD NOISE GENERATOR

The AIL Type 07004 Hot-Cold Standard Noise Generator cover frequencies from DC to 6 GHz. This is the most accurate noise generator commercially available. No external power supplies or terminations are required because this instrument operates by providing true thermal noise at two accurately known temperatures. The procedure for measuring noise figure using this instrument is the Y-factor method.

a. Refer to the handbook of the 07004 for the filling and stabilization procedures.

b. Connect the cold output of the noise generator to the system input, and make any initial adjustments (local-oscillator settings, etc.) required by the system under test. Check that the PRECISION ATTENUATOR is set to zero dB.

c. Set the METER switch to DETECTOR NORM.

d. Adjust the GAIN controls for a full-scale meter indication.

e. Set the METER switch to DETECTOR EXP.

f. Adjust the GAIN controls for a convenient reference reading.

g. Connect the system input to the hot termination.

h. Readjust the PRECISION ATTENUATOR until the meter returns to the reference set in step f.

i. The new setting of the PRECISION ATTENUATOR is the Y factor.

j. Refer to Figure 13 and read the system noise figure corresponding to the measured Y factor.

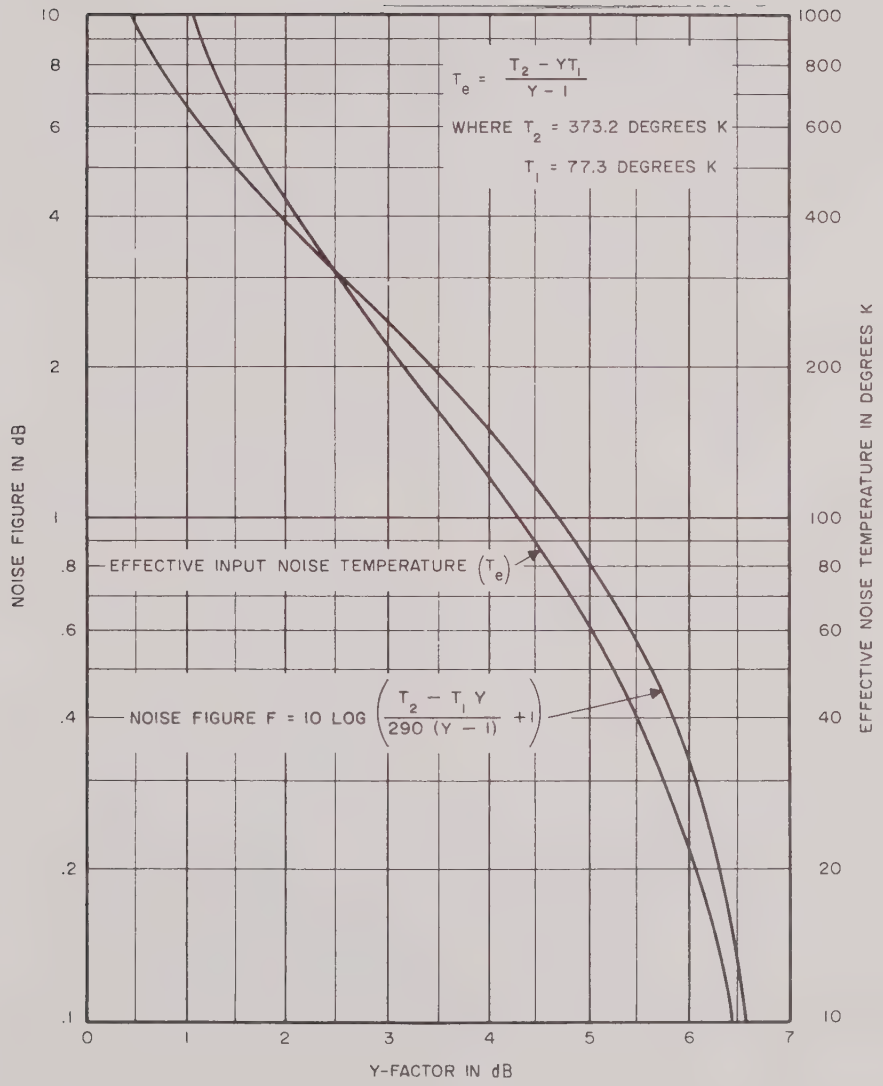


FIGURE 13. NOISE FIGURE AND EFFECTIVE INPUT-NOISE TEMPERATURE VS Y-FACTOR FOR TERMINATION TEMPERATURES OF 77.3 AND 373.2°K

SECTION 5. THEORY OF OPERATION

5.1 GENERAL

The Type 136 Receiver is essentially a highly stable, 30-MHz amplifier preceded by a precision IF attenuator and followed by a detector and display circuit. Figure 14 is a block diagram of the basic receiver showing the arrangement of the major components. This section describes the circuit theory of the various component parts of the receiver.

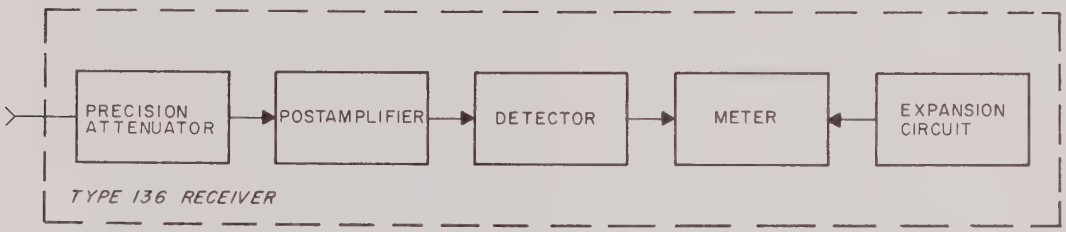


FIGURE 14. SIMPLIFIED BLOCK DIAGRAM OF BASIC TYPE 136 RECEIVER

5.2 PRECISION ATTENUATOR

The precision attenuator used in the Type 136 Receiver consists of a cylindrical cavity whose diameter is such that it forms a waveguide well below cutoff at the 30-MHz operating frequency. The launch coil is part of a piston that travels in an axial direction in the waveguide. This coil is tuned by a series capacitor, and the tuning elements are loaded with a series resistor to provide the proper input impedance.

The receiving coil is fixed at the opposite end of the waveguide. This coil is also tuned with a series capacitor and loaded with a series resistor, thus providing the 50-ohm output impedance.

True wave propagation does not exist in a waveguide below cutoff. The fields are exponentially attenuated down the length of the waveguide with a rate of attenuation that is determined by the transmission mode. For any single mode, the attenuation (in dB) is a linear function of the length of the waveguide.

The effective length of the waveguide can be changed by varying the separation between the coils. Thus, for a particular mode, the attenuation (in dB) can be read directly from the linear counter dials.

The primary transmission mode of the precision attenuator used in the Type 136 Receiver is a TE_{11} mode. This is the lowest mode that will propagate in a circular waveguide; it also has the lowest attenuation constant. If other modes are generated and propagate down the waveguide, they are attenuated faster than this primary mode of transmission.

If the separation between the two coils were reduced to where coupling to the spurious modes is significant, the linearity of the attenuation (in dB) versus distance characteristic of the attenuator would be affected. Consequently, in a practical device of this sort, it is necessary to provide a minimum separation between the radiating and receiving coils and, thus, preserve the accuracy of the attenuator.

This separation naturally introduces a fixed attenuation between the input and output of the precision attenuator which is called the minimum insertion loss of the device. Careful design of the radiating and receiving coils and selection of an optimum waveguide diameter allow such close coupling that the precision attenuator in a Type 136 Receiver exhibits a minimum insertion loss of less than 18 dB. This minimum loss is set such that there is no observable degradation in the linearity or accuracy of the attenuator over the first 10 dB of incremental attenuation.

5.3 POSTAMPLIFIER

The postamplifier (Figure 15) is a subassembly of the basic Type 136 Receiver. Figure 16 shows the component layout of the postamplifier. It consists of five stages of 30-MHz amplification, a detector, an emitter-follower IF output stage, and an emitter-follower video output stage. The unit is synchronously tuned to the center frequency of 30-MHz and has a bandwidth of 1 MHz. The gain is about 100 dB from the IF input to the second detector. The postamplifier has a nominal noise figure of 7 dB and a well-matched input impedance (less than 1.3 SWR).

5.3.1 INPUT STAGE

The first stage utilizes a 2N2996 transistor. This transistor was selected for its low-noise and high-gain characteristics. In order to minimize mismatch errors during attenuation measurements, the input matching network for this stage was designed to provide an impedance match for a 50-ohm system. Typically, the match provides an SWR of 1.2 to 1. The matching network utilizes a pi network that can provide high selectivity as well as the required impedance transformation.

5.3.2 INTERMEDIATE STAGES

The intermediate amplifier stages utilize 2N2996 transistors (Q2, Q3, and Q4). Interstage matching is accomplished by using pi (capacitive-divider) networks. Each stage is tuned by a variable inductor in the collector circuit. The collector of each stage is loaded by a resistor in the collector circuit and by the input impedance of the following stage (transformed through the pi network). The second and third stages are gain controlled as described in paragraph 5.3.8.

To minimize any bandwidth variations over the range of the gain control, the second- and third-stage output pi networks have been designed for a low Q. In comparison, the other tuned circuits in the postamplifier have a very high Q and, therefore, have a greater effect on the overall frequency response of the postamplifier. Bandwidth changes are extremely small (approximately 100 kHz) over the 50-dB range of the gain control.

5.3.3 POWER STAGE

Transistor Q5, the final amplifier stage in the postamplifier, is a 2N1141 high-frequency power transistor. The maximum output power of this stage during normal operation is about +3 dBm.

5.3.4 IF OUTPUT STAGE

Transistor Q7 is an emitter follower that provides a 30-MHz output. There is no tuning on this stage, and the 2N706 used will provide about 150 mV rms when loaded with 50 ohms.

5.3.5 DETECTOR

The postamplifier detector is a simple envelope detector consisting of CR3, a 1N87A germanium diode. Capacitor C29 is the detector filter capacitor, which is loaded by series resistor R20 and the display circuits.

5.3.6 VIDEO OUTPUT

A video output is available using a 2N706 transistor Q6, connected as an emitter follower. The rise time of the output pulse is limited by the bandwidth of the IF amplifier and does not exceed 1.5 μsec.

5.3.7 GAIN CONTROL

Two methods of gain control are used in the Type 136 postamplifier. The major control is effected by means of variable loading on the collectors of transistors Q2 and Q3, two of the intermediate-stage amplifiers. They are loaded by varying the DC current through diodes CR1 and CR2. These are HPA 3034 PIN diodes. As the current increases, the resistance of these diodes decreases, thereby loading the collectors and reducing the gain. In addition, fine gain control is provided by varying a shunt across the output meter.

5.4 MAIN CHASSIS

The rest of the receiver consists of the power supply and the switching and display circuits. These units are interconnected as shown in Figure 17.

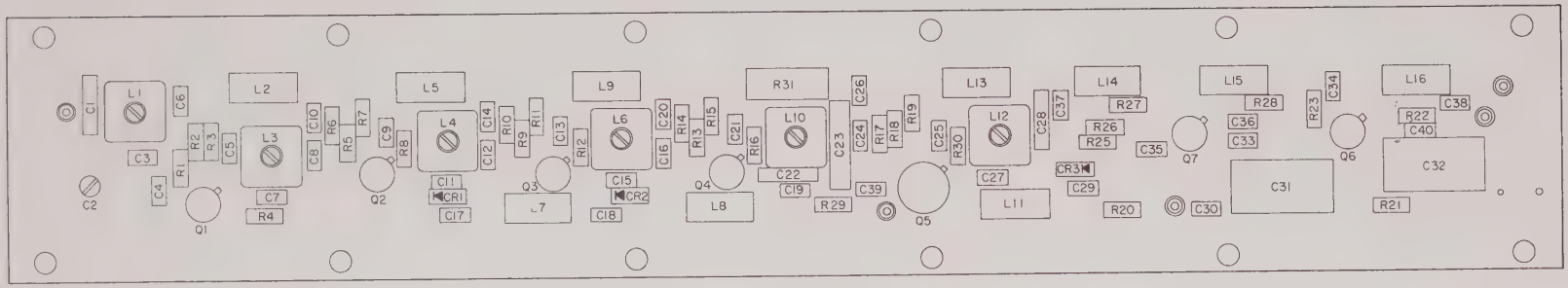


FIGURE 16. COMPONENT LAYOUT OF POSTAMPLIFIER

5.4.1 OUTPUT INDICATOR

The output indicator of the Type 136 Receiver is meter M1, whose function is controlled by switch S1. When S1 is in position 1 (CRYSTAL 3 MA), the meter and its multiplier resistor R8 are placed across one of two 100-ohm current-sampling resistors in the preamplifier being used. The full-scale range of the meter in this application corresponds to 3 mA of crystal current. Polarity is reversed by double-pole double-throw toggle switch S2. The desired crystal is selected by toggle switch S3.

When S1 is in position 2 (DETECTOR NORM), the postamplifier detector current is applied to the meter through resistors R6 and R7, which make up a 10-to-1 attenuator. Since the basic meter movement is 100 μa full scale, the postamplifier detector has to provide 1 ma of output current for full-scale deflection. The values of the resistors used in this attenuator are selected so that the load for the detector diode is always constant. The response of the output indicator is essentially linear; a 6-dB decrease in signal level will cause the meter indication to fall to one-half of its original reading.

When S1 is placed in position 3 (DETECTOR EXP), the attenuator is bypassed, and the full detector output is applied to the meter. Normally, this would cause the meter to deflect off scale; however, at the same time that the attenuator is bypassed, a bucking current is applied to the meter, which subtracts 90 percent of the original full-scale current. This procedure increases the overall display sensitivity by a factor of ten. Diode CR1, a 1N87A germanium diode, is connected across the meter terminals to protect the meter from reverse overload currents.

5.4.2 GAIN CONTROL

Potentiometers R1A, B and R2A, B are the COARSE and FINE GRAIN controls, respectively. These are dual potentiometers with ganged shafts. Potentiometer R1 is designed to compensate for the nonlinear voltage characteristic of the gain-control diodes. R2 functions as a variable shunt across the output meter and also causes a supplementary change in the bucking current.

5.4.3 PREAMPLIFIER CONNECTION

All connections to the wide-range or low-nose preamplifier, except the signal lead, are made through J1, the PREAMPLIFIER POWER jack. This front-panel receptacle is shielded from the rest of the receiver, and all leads are carefully filtered inside the shielded enclosure. This prevents feedback from the IF postamplifier to the preamplifier.

5.5 POWER SUPPLY

The power supply used in the Type 136 Receiver (Figure 18) is a modular unit designed to supply 40 volts to the internal postamplifier and to the external IF preamplifier. The dual primary windings on the power transformer permit the use of either a 115 or 230 volt input in the frequency range from 50 to 400 Hz. The rearrangement of jumpers required to make this change is shown in Figure 18. The regulation is less than 0.5 percent for line variations of $\pm$10 percent and load varations of one-half to full load.

A full-wave bridge rectifier, CR1 through CR4, is used to produce the main supply voltage. A single capacitor, C1, is used to filter its output. A voltage doubler consisting of CR5, CR6, C2, and C3 is used to provide a higher voltage to the amplifier in the voltage regulator circuit.

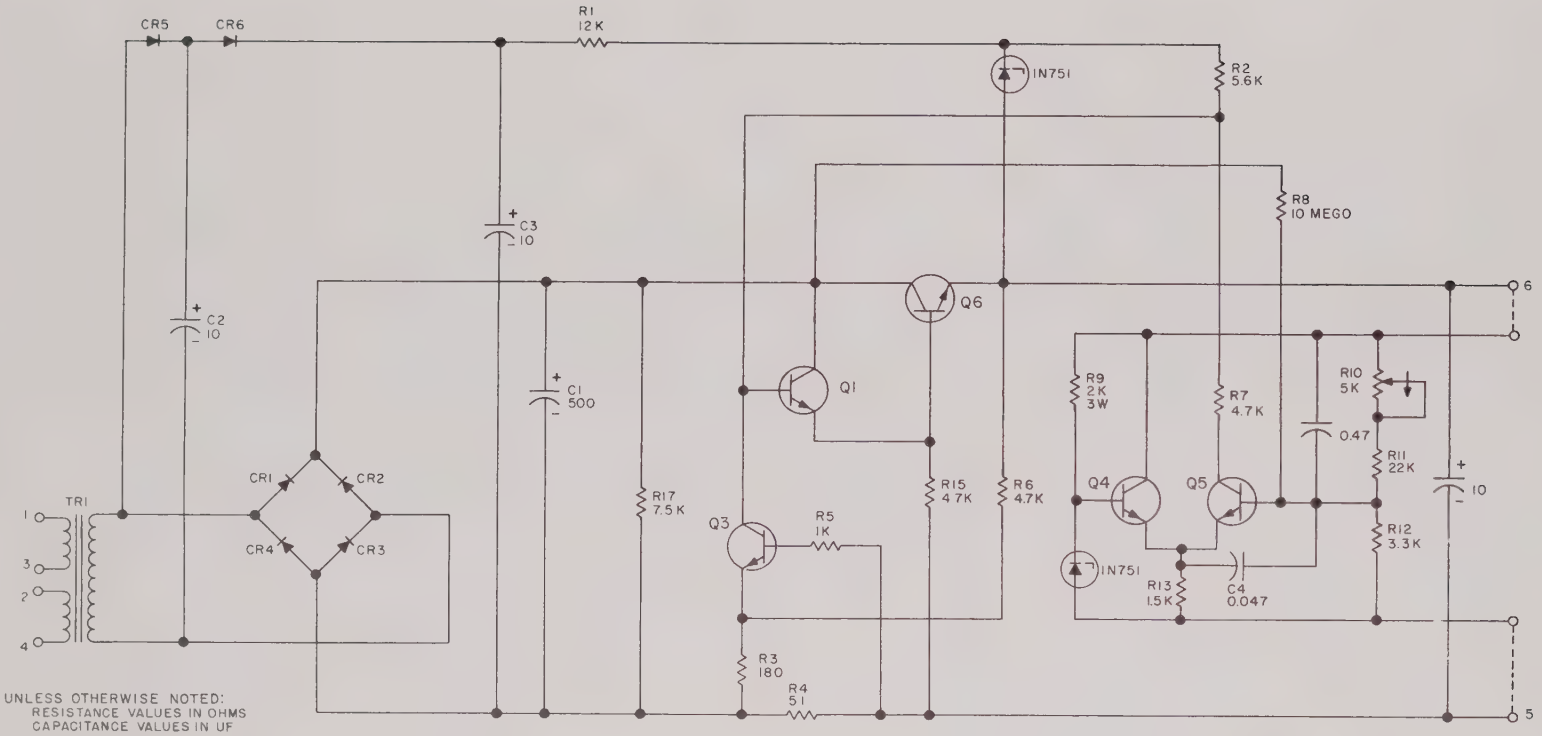


FIGURE 18. POWER SUPPLY, SCHEMATIC DIAGRAM

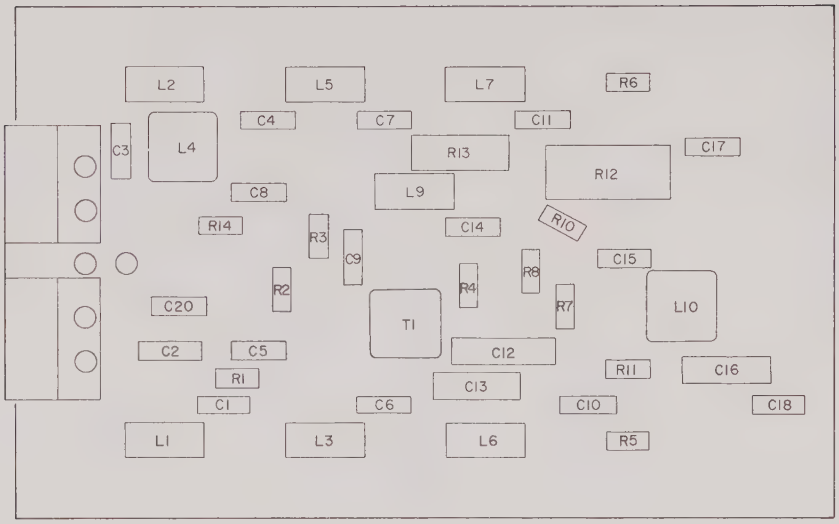
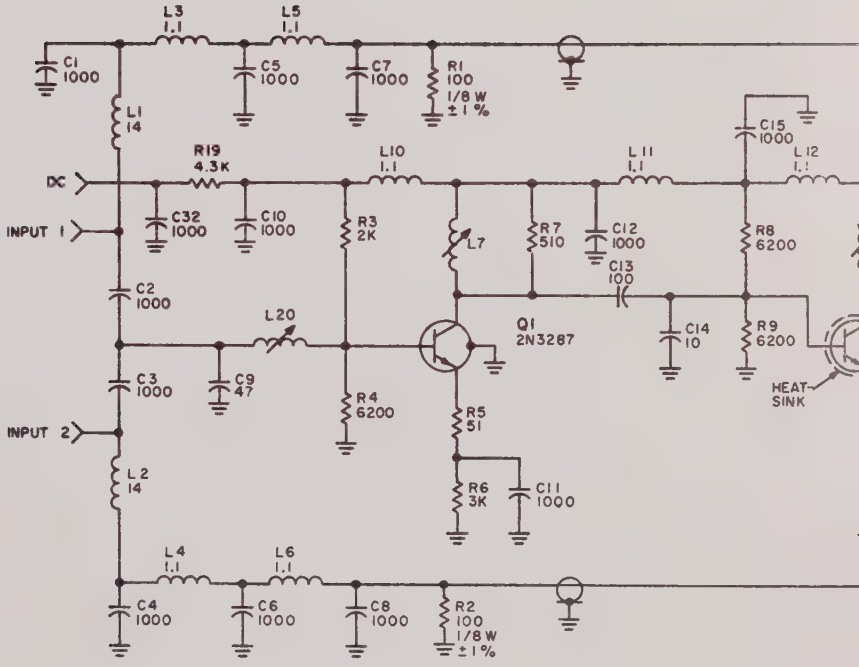


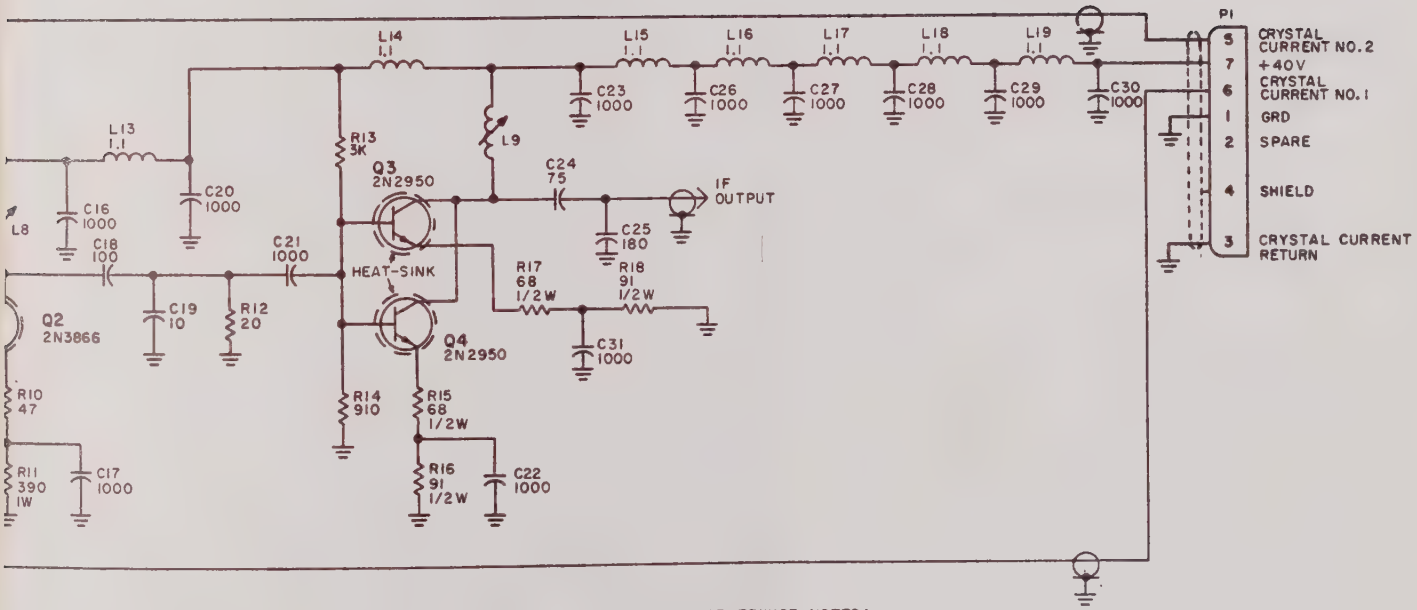
FIGURE 20. COMPONENT LAYOUT OF LOW-NOISE PREAMPLIFIER

5.7 WIDE-RANGE PREAMPLIFIER

The wide-range preamplifier (Figure 21) provides a wide RF attenuation measurement range through the selection of optimum values for gain, noise figure, and output power. Figure 22 shows the component layout of the wide-range preamplifier. The preamplifier output stage consists of two 2N2950 high-frequency power transistors operated in parallel. The intermediate stage also is a power transistor, whereas the first stage is a 2N3287.

Power circuits are generally noisy and although the front end is noise matched, the overall unit has a moderately high noise figure. However, the loss in dynamic range due to the higher noise level is insignificant compared with the increased range obtained by the high-power-handling capability.


L3
1.1
L5
1.1
C1
1000
C5
1000
C7
1000
R1
100
1/8 W
±1 %
L1
14
C15
1000
L12
1.1
R19
4.3K
L10
1.1
L11
1.1
DC
INPUT 1
C32
1000
C10
1000
R3
2K
L7
R7
510
C12
1000
R8
6200
C13
100
C2
1000
L20
Q1
2N3287
C14
10
R9
6200
HEAT-
SINK
C3
1000
C9
47
R4
6200
R5
51
INPUT 2
L2
14
R6
3K
C11
1000
L4
1.1
L6
1.1
C4
1000
C6
1000
C8
1000
R2
100
1/8 W
±1 %



SYM	INDUCTANCE UH
L7	0.45 - 0.75
L8	0.30 - 0.50
L9	0.30 - 0.50
L20	0.30 - 0.50

UNLESS OTHERWISE NOTED:
RESISTANCE VALUES IN OHMS, ± 5%, 1/4 W
CAPACITANCE VALUES IN PF

FIGURE 21. WIDE-RANGE PREAMPLIFIER (P/N 13650), SCHEMATIC DIAGRAM

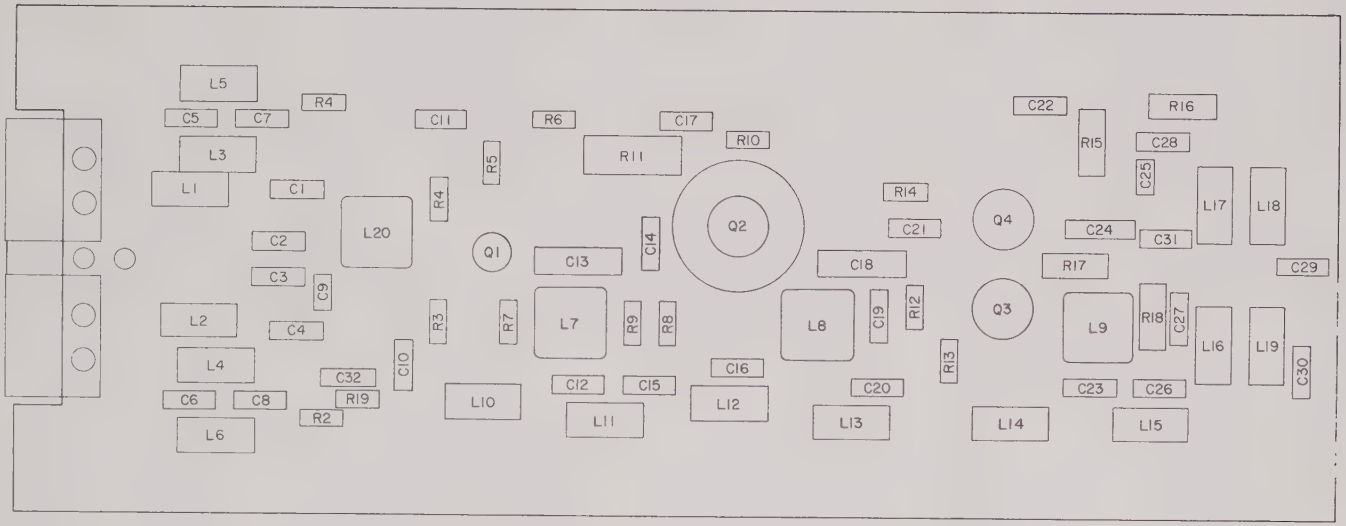


FIGURE 22. COMPONENT LAYOUT OF WIDE-RANGE PREAMPLIFIER

The input circuit is designed to accept a wide range of signal levels and can be operated from the same set of sources (mixers or adapters) as the low-noise preamplifier. The interstage coupling networks in the wide-range preamplifier are similar to those used in the postamplifier.

The preamplifier is tuned by collector inductance and the interstage capacitive transformers, such as C13 and C14 between Q1 and Q2. Careful attention has been paid to filtering the crystal current B+ lines because of the high power present in this circuit. In addition, a metallized flexible shielding gasket must always be used between the mixer or impedance adapter and either the low noise or wide range preamplifier in order to prevent signal leakage.

5.8 PREAMPLIFIER ADAPTERS

The 50-ohm adapter (Figure 23A) mechanically mates with either the wide-range or low-noise preamplifier. It permits these units to be used with 50-ohm 30-MHz and 60-80 MHz signal sources. Internally, the adapter consists of a ferrite transmission line transformer. This matching section transforms the 50-ohm source impedance to 200 ohms.

The 150-ohm adapter (Figure 23B) is similar in construction to the 50-ohm adapter except that it includes a permanently attached input cable. This unit enables the preamplifier to be used with commercially available mixers having a single ended output. The mixer output impedance should be 150 ohms for best noise-figure performance.

5.9 TUNABLE FREQUENCY CONVERTER

The tunable frequency converter (Figure 24) consists of a wide-band mixer and a variable-frequency oscillator. Figure 25 shows the component layout of the frequency converter. The oscillator is tunable by external adjustment of the frequency control knob. Electrical connection to the output of the mixer is by means of the PC board. This board mates with the spring clips located in the Type 136 preamplifiers.

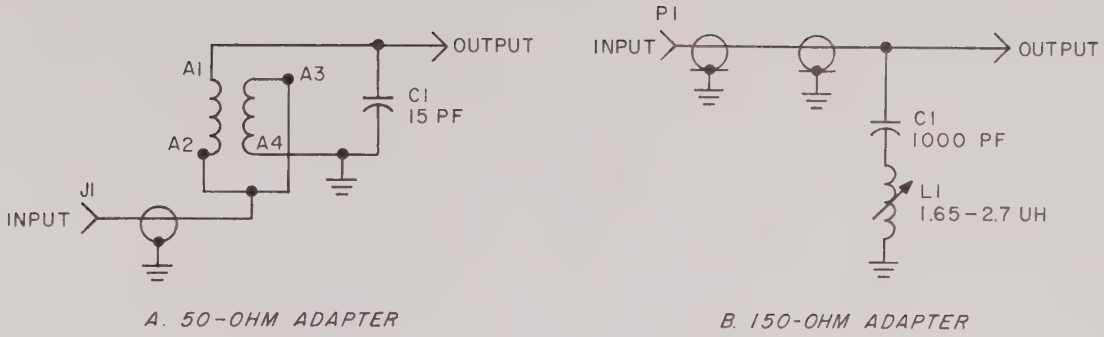


FIGURE 23. PREAMPLIFIER INPUT ADAPTERS, SCHEMATIC DIAGRAM

The mixer is doubly balanced; it incorporates wide-band toroidal transformers and hot-carrier diodes to provide high isolation and low conversion loss. The diodes are connected in a ring configuration. The IF output is at 30 MHz and is matched to the preamplifiers through an L network consisting of L1 and C1.

The oscillator is a high-gain 2N1742 transistor amplifier having wide-band feedback. The oscillator is tunable from 50 to 120 MHz. Tuning is accomplished by varying an air trimmer capacitor, C5. The capacitor is ungrounded at both of its terminals and is part of the tank circuit.

When converting a signal, whose frequency is between 40 and 90 MHz, to 30 MHz, lower sideband conversion is utilized. Similarly, when converting a signal whose frequency is between 90 and 150 MHz, upper sideband conversion is utilized. Since there is no preselector in the converter, various spurious and image frequencies will result in a receiver response. The main and spurious responses are shown in Figure 26.

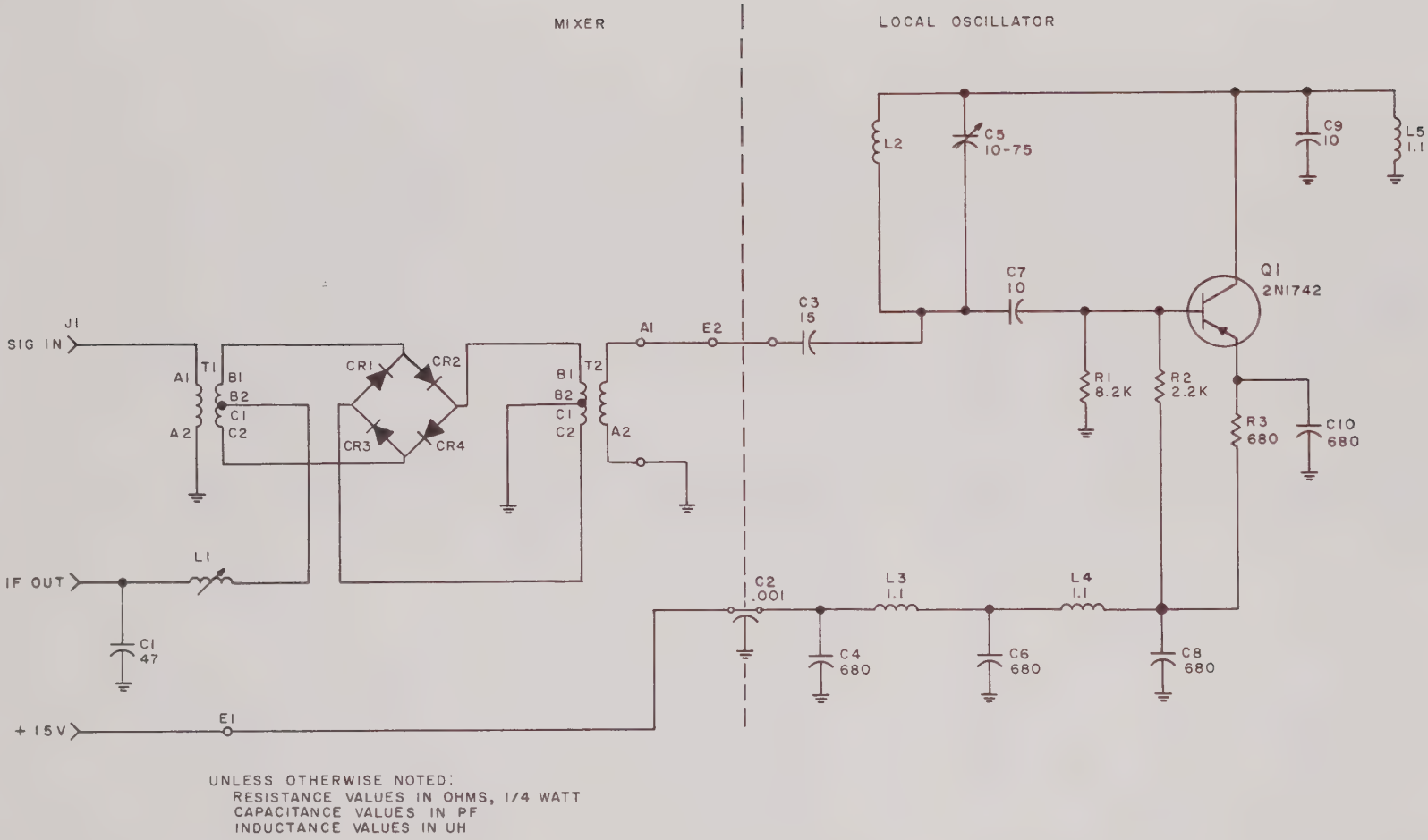
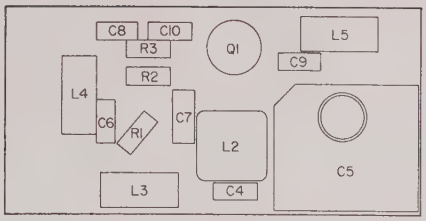
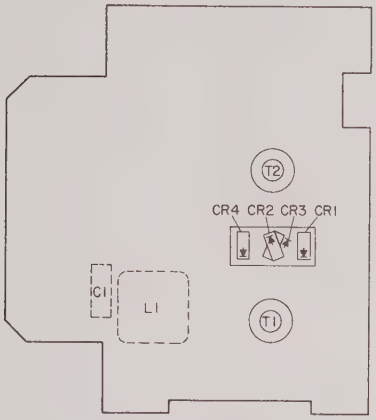


FIGURE 24. FREQUENCY CONVERTER, SCHEMATIC DIAGRAM



A. OSCILLATOR PC LAYOUT



B. MIXER PC LAYOUT

FIGURE 25. COMPONENT LAYOUT OF FREQUENCY CONVERTER

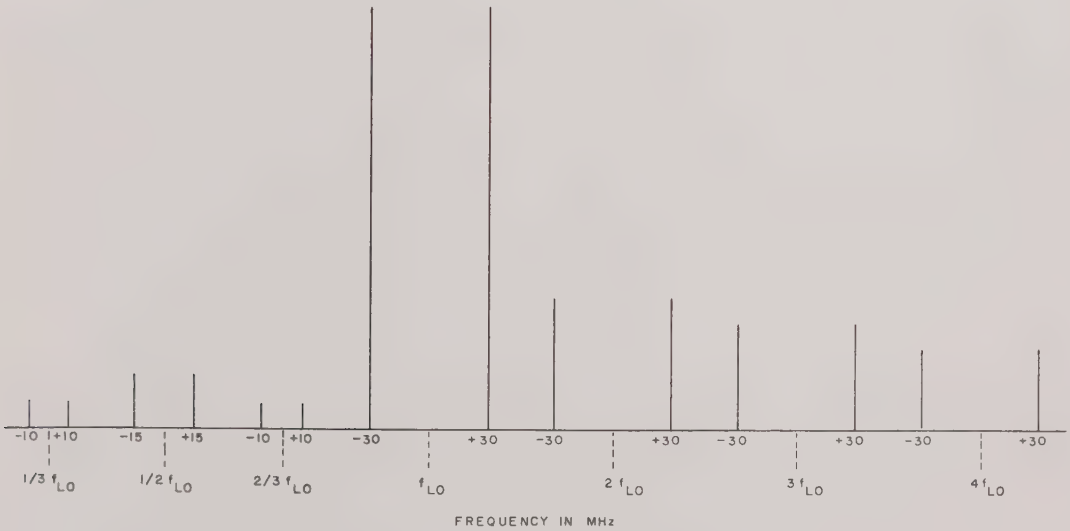


FIGURE 26. DESIRED AND MAIN SPURIOUS RESPONSE OF FREQUENCY CONVERTER

SECTION 6. MAINTENANCE INSTRUCTIONS

6.1 GENERAL

The use of solid-state components for all active elements and the selection of high-quality components throughout assures a long, trouble-free life for this receiver. The entire receiver is guaranteed against defects in materials and workmanship, as stated in the warranty located inside the front cover of this handbook. Routine maintenance will generally be limited to lubrication of the precision attenuator as described below.

6.2 PRECISION ATTENUATOR

Maintenance of the precision attenuator is limited to lubrication of the drive mechanism semiannually. Crank the piston out about 1/2 inch from the fully seated position; then apply one drop of light instrument oil to the bearings and the piston. To distribute the oil, turn the drive shaft so that the piston is moved in and out over its full range.

CAUTION

Do not use an excessive amount of oil because oil inside the piston or the sleeve can cause electrical malfunction. Do not attempt to disassemble the unit or make gear train adjustments. Return the unit to the manufacturer for any repairs.

6.3 MAIN CHASSIS

The wiring of all panel controls and indicators and the interwiring between subassemblies is shown in Figure 16.

6.3.1 AC POWER

Turn on the power switch; the indicator light should operate. If not, check for 115 VAC across the AC power receptacle (J8). If the voltage is correct, change the bulb, DS1.

6.3.2 POWER SUPPLY

Connect a DC voltmeter across the power supply and then turn on the AC power. The voltmeter should read 40 ±0.5 volts from terminal 6 to ground. If this condition is not met, the voltage adjust potentiometer located in the power supply should be adjusted.

The output voltage of the supply is electronically regulated and is protected against the effect of excessive load current. The schematic diagram is shown in Figure 18. Troubleshooting can be readily accomplished by checking the voltages shown in paragraph 6.8.4 taken under normal operating conditions without any preamplifier connected to the preamplifier power connector on the front panel.

6.3.3 PREAMP POWER JACK

Measure the voltage at pin 3. It should read about 40 volts. If not, check for circuit continuity as shown in Figure 17.

Throw the meter switch to 3 MA position, the crystal switch to 1 position, and the polarity switch to + position. Connect a jumper between pin 9 and ground. Connect a 0.1 VDC source to pin 4. The meter should read between 0.9 and 1.1 ma. Remove the jumper, connect the source to pin 9 and ground pin 4. Throw the polarity switch to - position. The meter should read between 0.9 and 1.1 ma. If the meter does not read properly, check switches S1, S2, and S3 for proper operation.

Throw the meter switch to 2 position and repeat the preceding test using pins 7 and 9.

6.3.4 VIDEO OUTPUT

Connect a 30-MHz generator to the receiver "Input." Set the output of the generator to -70 dbm, CW. Adjust the gain control for a deflection of 100 with the selector switch in the "Normal" position. Switch the signal generator to 400-cycle modulation and adjust the modulation level to 60 percent. A VTVM connected to the video output should read approximately 600 mv rms. If not, refer to Section 6.4.

6.4 POSTAMPLIFIER, P/N 13640

The schematic diagram of the postamplifier is shown in Figure 15. Because of the long-term stability of this solid-state amplifier, all tuning adjustments are permanently secured. Retuning or other major repairs can best be handled by the manufacturer. However, when this is not practical, the following maintenance procedure may be used. Connect a 30-MHz signal generator to the receiver "Input." Set the generator to -90 dbm, CW. Turn the receiver gain to a maximum; the meter should deflect to 100 or greater when the selector position is in the "Normal" position. If not, determine the generator output level that will result in a full-scale deflection. If the generator output is approximately -85 dbm or lower, check the alignment of the amplifier in accordance with the theory of operation given in paragraph 5.3. If the generator output is approximately -75 dbm, then check for a malfunction of transistors Q1 through Q5, and Q7 in accordance with the DC voltage chart of paragraph 6.8.1.

To check the video output of the amplifier, switch the signal generator to 400 cycle modulation, 60 percent. Adjust the receiver gain to approximately full-scale deflection. If the voltage (VTVM) is not approximately 600 mv rms, check for a malfunction of transistor Q6 in accordance with the DC voltage chart of paragraph 6.8.1. If this transistor is functioning properly, check capacitors C31 and C32.

6.5 LOW-NOISE PREAMPLIFIER, P/N 13630

The schematic diagram of the preamplifier is shown in Figure 18. Because of the long-term stability of this solid-state amplifier, all tuning adjustments are permanently secured. Retuning or other major repairs can best be handled by the manufacturer. However, when this is not practical, the following maintenance procedure may be used. Attach a 50-ohm adapter (AIL Part No. 208393) to the preamplifier. (If this adapter is not available, a suitable mixer known to be operating properly may be used in its place. However, the proper RF and local oscillator inputs must be used and an allowance must be

used and an allowance must be made for the conversion loss and noise figure of the mixer.) Connect a 30-MHz generator to the adapter input. Set the generator output to -60 dbm. Measure the output power of the amplifier--it should be greater than -13 dbm. If it is less than -13 dbm but greater than -20 dbm, check the preamplifier alignment in accordance with the theory of operation given in paragraph 5.6. If the amplifier output power is less than -20 dbm, then check for a malfunction of transistors Q1 and Q2 in accordance with the DC voltage, paragraph 6.8.2. It is recommended that the alignment of the coils should be in the following order: T1, L4, and L10. Next, with the generator disconnected, tune C19 for a minimum voltage output as observed on an RF voltmeter. To obtain a minimum noise figure, L4 may have to be slightly retuned and consequently T1 and L10 readjusted to maintain the center frequency of the amplifier. This process converges very rapidly.

6.6 WIDE-RANGE PREAMPLIFIER, P/N 13650

The schematic diagram of the preamplifier is shown in Figure 19. Because of the long-term stability of this solid-state amplifier, all tuning adjustments are permanently secured. Retuning or other major repairs can best be handled by the manufacturer. However, when this is not practical, the following maintenance procedure may be used. Attach a 50-ohm adapter (AIL Part No. 208393) to the preamplifier. Connect a 30-MHz generator the the amplifier input. (If this adapter is not available, a suitable mixer known to be operating properly may be used in its place. However, the proper RF and local oscillator inputs must be used an an allowance must be made for the conversion loss and noise figure of the mixer.) Set the generator output to -40 dbm. Measure the output power of the amplifier--it should be greater than -13 dbm. If it is less than -13 dbm but greater than -20 dbm, check the preamplifier alignment in accordance with the theory of operation given in paragraph 5.7. If the amplifier output power is less than -20 dbm, then check for a malfunction of transistors Q1 through Q4 in accordance with the DC voltage chart of paragraph 6.8.3

The chassis cover is used as a heat sink for transistors Q3 and Q4. To take the cover off, it is necessary to first remove the two screws located near the nameplate.

CAUTION

When operating with the cover off, provide a suitable heat sink for transistors Q3 and Q4.

It is recommended that the coils be synchronously tuned in the order of L20, L7, L8, and L9.

6.7 TUNABLE FREQUENCY CONVERTER, P/N 13635

The schematic diagram of the converter is shown in Figure 21. Because of the long-term stability of this solid-state amplifier, all tuning adjustments are permanently secured. Retuning or other major repairs can best be handled by the manufacturer. However, when this is not practical, the following maintenance procedure may be used.

To check for proper oscillator power output, remove the cover from the enclosure, connect +15-volts DC to the turret lug on the mixer board and ground the negative lead. The DC current should read between 5.6 and 6.0 ma. If not check for a malfunction of transistor Q1 in accordance with the DC voltage chart of paragraph 6.8.5.

Measure the RF voltage at the barrier side of C3; it should be at least +3 dbm (use high impedance probe). If not replace transistor Q1.

Check the isolation between the barrier side of C3 and the IF output (PC board). The isolation should be approximately 30 db. Check the isolation between the barrier side of C3 and the signal port, and similarly between the signal port and the IF output. The isolation should be approximately 20 db. If the isolation is much lower, check for malfunction of diodes CR1, 2, 3, or 4.

6.8 DC VOLTAGE CHARTS*

6.8.1 POSTAMPLIFIER, P/N 13640

	V_E	V_B	V_C
Q_1	7.8	7.5	0
Q_2	6.2	5.8	0
Q_3	6.2	5.8	0
Q_4	6.2	5.8	0
Q_5	11.0	10.7	0
Q_6	12.3	13.0	21.0
Q_7	12.3	13.0	21.0

Note:

Coarse and fine gain controls set at minimum.

* Measured with VTVM.

6.8.2 LOW-NOISE PREAMPLIFIER, P/N 13630

	V_E	V_B	V_C
Q_1	7.6	7.2	0
Q_2	7.6	7.2	0

6.8.3 WIDE-RANGE PREAMPLIFIER, P/N 13650

	V_E	V_B	V_C
Q_1	28.5	29.0	40
Q_2	17.2	17.8	40
Q_3	5.8	6.5	40
Q_4	5.8	6.5	40

6.8.4 POWER SUPPLY

	V_C	V_E	V_B
Q_1	58.0	41.0	41.5
Q_3	41.5	- 0.35	0
Q_4	40.0	4.5	5.1
Q_5	40.0	4.5	5.0
Q_6	58.0	40.0	41.0

6.8.5 TUNABLE FREQUENCY CONVERTER, P/N 13635

	V_C	V_E	V_B
Q_1	0	12.5V	11.8V

6.9 FACTORY REPAIR

If the equipment is to be returned to the manufacturer for repair, please follow these instructions.

1. Write to the AIL Microwave Instruments Department, giving complete information concerning the failure and the manner in which the equipment was being used when failure occurred. Include the unit TYPE and SERIAL numbers.

2. Special shipping instructions will be supplied by AIL. Pack and ship the equipment as directed. Transportation charges should be prepaid, and a failure report should be supplied with the equipment.

SECTION 7. LIST OF REPLACEABLE PARTS

7.1 MAIN CHASSIS (P/N 13610)

Reference Symbol	Description	Manufacturer	Part Number
C1, 3, 5	Capacitor, standoff 1000 pf	Allen-Bradley	FB2B
C2, 4, 6, 7	Capacitor, feedthru 1000 pf	Allen-Bradley	SB4A
CR1	Diode		1N87A
F1, 2	Fuse, 1/2 amp		FO2B250V1/ 2AS
J1	Connector	Deutsch	754-7-0SN
L1, 2, 3	Inductor, molded, 1.1 μh	Speers Carbon Co.	10101-1
M1	Meter	AIL	304919
P1	Cable and plug assy	AIL	990050
R1, 2	Resistor, variable dual, 10 to 25 k	AIL	115289-15
R3	Resistor, fixed, 200 ohm, 10 w	Sprague	247E2015
R4, 6	Resistor, fixed, 9.1 k, 1/4 w		RC07GF912J
R5	Resistor, fixed, 4.3 k, 1/4 w		RC07GF432J
R7	Resistor, fixed, 1 k, 1/4 w		RC07GF102J
R8	Resistor, fixed, 1.9 k, 1 w	Ward Leonard	1SX
R9	Resistor, fixed, 3.9 k, 1/4 w		RC07GF392J
R10	Resistor, fixed, 2.7 k, 1/4 w		RC07GF272J
R11	Resistor, fixed, 20 k, 1 w		RC32GF203J
R12	Resistor, fixed, 18 k, 1 w		RC32GF183J

Reference Symbol	Description	Manufacturer	Part Number
S1	Switch, rotary	Standard Grigsby	Type 4MF
S2	Switch, small motor DPDT	Cutler-Hammer	8363
S3	Switch, small motor SPDT	Cutler-Hammer	8282K14
S4	Switch, pushbutton	AIL	211824
	Attenuator, precision	AIL	03230

7.2 POSTAMPLIFIER (P/N 013640)

C1	Capacitor, glass 130 pf ±5%	Corning	TY06-131J
C2	Capacitor, trimmer 10 to 75 pf	Erie	557-091-N1500 (P3PO)10-75Pf (109R)
C3	Capacitor, glass 20 pf ±5%	Corning	TY06-200J
C4, 5, 6, 9, 10, 13, 14 17 through 21, 25, 26, 30, 33 through 39	Capacitor, ceramic 1000 pf ±10%	---	CK05CW102K
C7	Capacitor, ceramic 270 pf ±10%	---	CK05CW271K
C8, 29	Capacitor, ceramic 680 pf ±10%	---	CK05CW681K
C11, 12, 15, 16, 40	Capacitor, ceramic 100 pf ±10%	---	CK05CW101K
C22	Capacitor, ceramic 240 pf ±5%	Erie	N750-8141
C23	Capacitor, ceramic 470 pf ±5%	Erie	N750-8161
C24, 27	Capacitor, ceramic 150 pf ±10%	---	CK05CW151K
C28	Capacitor, ceramic 150 pf ±5%	Erie	N330-8141

Reference Symbol	Description	Manufacturer	Part Number
C31, 32	Capacitor, electrolytic, 15 μf, 25 v	Sprague	TE1205
C41, 42 43	Capacitor, feedthru 1000 pf	Allen-Bradley	SB4A
CR1, 2	Diode	---	HPA 3039
CR3	Diode	---	1N87A
L1	Inductor, variable	AIL	118244-3
L3, 10	Inductor, variable	AIL	118244-11
L2, 13 through 16, 5, 7, 8, 9	Inductor, molded 1.1 μh	Speers Carbon Co.	10101-1
L4, 6, 12	Inductor, variable	AIL	118244-1
L11	Inductor, molded 3 μh	Speers Carbon Co.	10100-2
Q1 through Q4	Transistor		2N2996
Q5	Transistor	Texas Instruments only	2N1141
Q6, 7	Transistor		2N706
R1	Resistor, fixed, comp, 2.7 k ±5%, 1/4 w	---	RC07GF272J
R2	Resistor, fixed, comp, 1.5 k ±5%, 1/4 w	---	RC07GF152J
R3, 5, 6, 9, 10, 13, 14	Resistor, fixed, comp, 2 k ±5%, 1/4 w	---	RC07GF202J
R4, 16	Resistor, fixed, comp, 820 ohms ±5%, 1/4 w	---	RC07GF821J
R7, 11, 15	Resistor, fixed, comp, 680 ohms ±5%, 1/4 w	---	RC07GF681J
R8, 12, 17, 18	Resistor, fixed, comp, 1 k ±5%, 1/4 w	---	RC07GF102J
R19	Resistor, fixed, comp, 560 ohms ±5%, 1/4 w	---	RC07GF561J
R20	Resistor, fixed, comp, 1.3 k ±5%, 1/4 w	---	RC07GF132J

Reference Symbol	Description	Manufacturer	Part Number
R21, 25, 26	Resistor, fixed, comp, 5.6 k ±5%, 1/4 w	---	RC07GF562J
R22, 28	Resistor, fixed, comp, 1.2 k ±5%, 1/4 w	---	RC07GF122J
R23, 27	Resistor, fixed, comp, 3.3 k ±5%, 1/4 w	---	RC07GF332J
R29, 30	Resistor, fixed, comp, 11 ohms ±5%, 1/4 w	---	RC07GF110J
R31	Resistor, fixed, comp, 560 ohms ±5%, 1 w	---	RC32GF561J

7.3 LOW-NOISE PREAMPLIFIER (P/N 13630)

C1, 2, 3, 4 5, 6, 7, 8, 9, 10, 11, 14, 15, 17, 20	Capacitor, disc, ceramic, 1000 pf 1000 v	Centralab	DD-102
C12	Capacitor, ceramicon 150 pf, 200 v	Erie Resistor Corp.	NP08151
C13	Capacitor, ceramicon 51 pf, 200 v	Erie Resistor Corp.	NP08141
C16	Capacitor, ceramicon 100 pf, 200 v	Erie Resistor Corp.	NP08151
C18	Capacitor, ceramic, 220 pf, 300 v	Corning	TY06-221J
C19	Capacitor, variable, 2 to 8 pf	Erie	538-011-89R
J1	Connector, BNC		UG625/U
L1, 2	Inductor, molded, 14 μh	AIL	115297-2
L3, 5, 6, 7, 9,	Inductor, molded, 1.1 μh	Speers Carbon Co.	10101-1
L4	Inductor, variable	AIL	118244-3
L10	Inductor, variable	AIL	118244-1
P1	Connector, power	Deutsch	757-7-OPN-059
R1, 7	Resistor, fixed, 3 k, 1/4 w	---	RC07GF302J

Reference Symbol	Description	Manufacturer	Part Number
R2, 8	Resistor, fixed, 3.6 k, 1/4 w	---	RC07GF362J
R3	Resistor, fixed, 1.8 k, 1/4 w	---	RC07GF182J
R4	Resistor, fixed, 270, 1/4 w	---	RC07GF271J
R5, 6	Resistor, carbon, film, 100, 1/8 w	Texas Instruments	CR 1/8
R10	Resistor, fixed, 1 k, 1/4 w	---	RC07GF102J
R11	Resistor, fixed, 510, 1/4 w	---	RC07GF511J
R12	Resistor, fixed, 430, 2 w	---	RC42GF431J
R13	Resistor, fixed, 470, 1 w	---	RC32GF471J
R14	Resistor, fixed, 100, 1/4 w	---	RC07GF101J
Q1	Transistor	AIL	209376
Q2	Transistor	---	2N2996
T1	Transformer, RF	AIL	208935

7.4 POWER SUPPLY (P/N 207930)

C1	Capacitor, electrolytic, 500 μf, 75 v	General Electric	43F3017MA6
C2, 3, 6	Capacitor, electrolytic, 10 μf, 150 v	Sprague	TE1507
C4	Capacitor, paper, 0.047 μf, 100 v	Cornell Dublier	WMF 1S47
C5	Capacitor, paper, 0.47 μf, 100 v	Cornell Dublier	WMF 1P47
CR1, 2, 3, 4, 5, 6	Diode, silicone	---	1N2071
CR7, 8	Diode, zener	---	1N751
Q1	Transistor	---	2N3568
Q3, 4, 5	Transistor	---	2N3416

Reference Symbol	Description	Manufacturer	Part Number
Q6	Transistor	---	2N3442
R1	Resistor, fixed, film, 12 k, 1/2 w	---	RL20S123J
R2	Resistor, fixed, film, 5.6 k, 1/2 w	---	RL20S562J
R3	Resistor, fixed, film, 180 ohms, 1/2 w	---	RL20S181J
R4	Resistor, fixed, comp, 5.1 ohms, 1 w	---	RC32GF5RW
R5	Resistor, fixed, film, 7 k, 1/2 w	---	RL20C102J
R6	Resistor, wirewound, 4.7 k, 3 w	Sprague	242E
R7	Resistor, fixed, film, 4.7 k, 1/2 w	---	RL20C472J
R8	Resistor, fixed, film, 10 meg, 1/2 w	---	RL20C106J
R9	Resistor, wirewound, 2 k, 3 w	Sprague	242E
R10	Resistor, variable, wirewound, 5 k	1RC	BK64271
R11	Resistor, fixed, film, 22 k, 1/2 w	---	RL20C223J
R12	Resistor, fixed, film, 3.3 k, 1/2 w	---	RL20C332J
R13	Resistor, fixed, film, 1.5 k, 1/2 w	---	RL20C152J
R15	Resistor, fixed, film, 4.7 k, 1/2 w	---	RL20C472J
R17	Resistor, fixed, comp, 7.5 k, 1/2 w	---	RC20GF752J
T1	Transformer, power	Power Mate	A20418-3
7.5	50-OHM ADAPTER (P/N 208393)		
C1	Capacitor, ceramic, 15 pf	---	CK05BX150K
T1	Transformer	AIL	210699

Reference Symbol	Description	Manufacturer	Part Number
7.6	150-OHM ADAPTER (P/N 208550)		
C1	Capacitor, ceramic, 1000 pf	---	CK60AW102M
L1	Inductor, variable	AIL	118244-6
7.7	HIGH-POWER PREAMPLIFIER (P/N 013650)		
C1 through 8, 10, 11, 12, 15, 16, 17, 20 through 23, 26 through 31	Capacitor, disc, ceramic, 1000 pf	Centralab	DD-102
C9	Capacitor, disc, ceramic, 47 pf	---	CK05CW470K
C13, 18	Capacitor, ceramic, 100 pf	Erie	NPO 8151
C14, 19	Capacitor, ceramic, 10 pf	Erie	865-000-P3K-100J
C24	Capacitor, ceramic, 75 pf	Erie	NPO 8141
C25	Capacitor, ceramic, 180 pf	---	CK05CW181K
L1, 2	Inductor, molded, 14 μh	Speers Carbon Co.	10102-1
L3 through 6, 10 through 19	Inductor, molded, 1.1 μh	Speers Carbon Co.	10101-1
L7	Inductor, variable	AIL	118244-2
L8, 9, 20	Inductor, variable	AIL	118244-1
P1	Connector, plug, elec, male	Deutsch	757-7-OPN-059
Q1	Transistor	---	2N3287
Q2	Transistor	---	2N3866
Q3, 4	Transistor	Motorola	2N2950

Reference Symbol	Description	Manufacturer	Part Number
R1, 2	Resistor, fixed, 100 ohms, 1/8 w	Texas Inst	CR 1/8
R3	Resistor, fixed, 2 k, 1/4 w	---	RC07GF202J
R4, 8, 9	Resistor, fixed, 6.2 k, 1/4 w	---	RC07GF622J
R5	Resistor, fixed, 51 ohms, 1/4 w	---	RC07GF510J
R6, 13	Resistor, fixed, 3 k, 1/4 w	---	RC07GF302J
R7	Resistor, fixed, 510 ohms, 1/4 w	---	RC07GF511J
R10	Resistor, fixed, 47 ohms, 1/4 w	---	RC07GF470J
R11	Resistor, fixed, 390 ohms, 1 w	---	RC32GF391J
R12	Resistor, fixed, 20 ohms, 1/4 w	---	RC07GF200J
R14	Resistor, fixed, 910 ohms, 1/4 w	---	RC07GF911J
R15, 17	Resistor, fixed, 68 ohms, 1/2 w	---	RC20GF680J
R16, 18	Resistor, fixed, 91 ohms, 1/2 w	---	RC20GF910J
R19	Resistor, fixed, 4.3 k, 1/4 w	---	RC07GF432J

7.8 TUNABLE FREQUENCY CONVERTER (P/N 13635)

C1	Capacitor, fixed, 47 pf	Corning	TY06-470J
C2	Capacitor, feedthru, 1000 pf	Allen-Bradley	SB4A
C3	Capacitor, fixed, 15 pf $\pm$5%	Corning	TY06-150J-10
C4, 6, 8, 10	Capacitor, fixed, 680 pf	---	CK60AW681M
C5	Capacitor, variable	Hammarlund	MAPC-75
C7	Capacitor, fixed, 10 pf	Corning	TY06-100J-171

Reference Symbol	Description	Manufacturer	Part Number
C9	Capacitor, fixed, 10 pf 5%	Erie	831-000-P3K-100J
CR1, 2, 3, 4	Diode, quad	Texas Instruments	A1047-4
J1	Connector, type N	AIL	211330
L1	Inductor, variable	AIL	118244-1
L2	Inductor, variable	AIL	210869
L3, 4, 5	Inductor, molded, 1.1 μh	Speers Carbon Co.	10101-1
Q1	Transistor	---	2N1742
R1	Resistor, fixed, 8.2 k, 1/4 w	---	RC07GF822J
R2	Resistor, fixed, 2.2 k, 1/4 w	---	RC07GF222J
R3	Resistor, fixed, 680, 1/4 w	---	RC07GF681J
T1, 2	Transformer	AIL	210699

APPENDIX A

TECHNIQUES OF ATTENUATION MEASUREMENT

1. INSERTION-LOSS DEFINITION

The insertion loss of a two-port network can be defined as that decrease in transmitted power that occurs when a uniform transmission line, having a matched source at one end and a matched load at the other end, is interrupted by the insertion of the network. Referring to the circuit of Figure A-1, insertion loss L can be expressed in terms of the relation between the power available from the matched generator P_G and the power absorbed by the matched load P_L. This relation is shown in normalized form in equation A-1

$$L = 1 - \frac{P_L}{P_G} \tag{A-1}$$

The above definition of insertion loss includes two separate effects: attenuation, and reflection loss. Some of the power entering the network is dissipated within the network. This loss can be defined as the attenuation of the network. In addition, if there is an impedance mismatch at either one or both ports of the network, a portion of the incident power is reflected back toward the generator, causing losses that are referred to as reflection losses.

Insertion loss can be expressed as the sum of these losses:

$$L = L_A + L_i + L_o \tag{A-2}$$

where

L = Insertion loss (dB)

L_A = Loss due to attenuation (dB)

L_i = Loss due to mismatch at the attenuator input (dB)

L_o = Loss due to mismatch at the attenuator output (dB)

2. MISMATCH ERRORS IN ATTENUATION MEASUREMENT

The reflection losses at the two ports of the network vary, depending on the actual source and load impedances in the measurement system. These variations cause an uncertainty whose limits can be calculated as follows.

The reflection losses in the matched system of Figure A-1 are equal to

$$L_i = \left| r_i \right|^2 \tag{A-3}$$

$$L_o = \left| r_o \right|^2 \tag{A-4}$$

where

r_i = Reflection coefficient of attenuator input

r_o = Reflection coefficient of attenuator output

In the practical measurement system (Figure 2) the reflection losses may differ from the values given above because of the mismatched generator and load. The measured reflection loss at the input port may be either greater or less than the desired value and will fall within the following limits:

$$L_1 = \left| r_1 \right|^2 \tag{A-5}$$

where

$$r_1 = \frac{S_1 - 1}{S_1 + 1} \tag{A-6}$$

and

$$\frac{S_G}{S_i} \leq S_1 \leq S_G S_i \tag{A-7}$$

L_1 = Measured reflection losses at attenuator input

S_1 = Effective SWR of combination of generator-output and attenuator-input impedances

S_i = SWR of attenuator input impedance

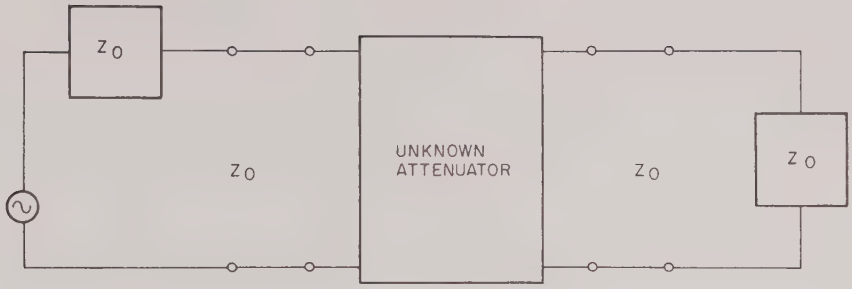


FIGURE A-1. ASSUMED CONDITIONS FOR DEFINITION OF INSERTION LOSS

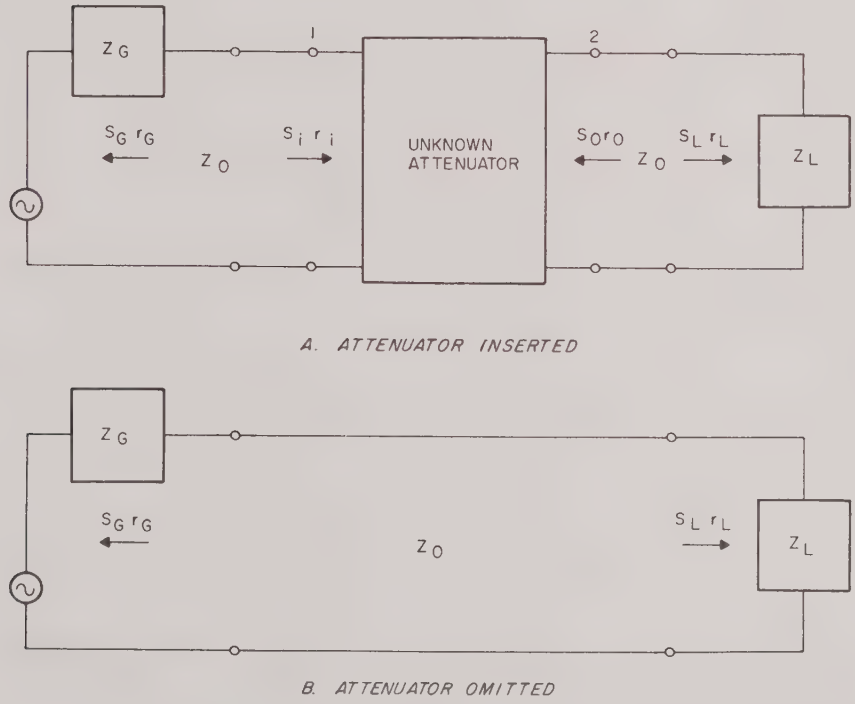


FIGURE A-2. ACTUAL CONDITIONS FOR MEASUREMENT OF INSERTION LOSS

S_G = SWR of generator output impedance

r_1 = Reflection coefficient corresponding to S_1

The difference between the measured mismatch loss and the theoretical mismatch loss constitutes an uncertainty E_1.

$$E_1 = L_1 - L_i \tag{A-8}$$

$$E_1 = \left|r_1\right|^2 - \left|r_i\right|^2 \tag{A-9}$$

Similarly, a corresponding uncertainty in measurement E_2 occurs as a result of the mismatch of the load.

$$E_2 = \left|r_2\right|^2 - \left|r_o\right|^2 \tag{A-10}$$

where

$$r_2 = \frac{S_2 - 1}{S_2 + 1} \tag{A-11}$$

$$\frac{S_o}{S_L} \leq S_2 \leq S_o S_L \tag{A-12}$$

S_o = SWR of the attenuator output impedance

S_L = SWR of the load impedance

S_2 = Effective SWR of the combination of the load and the attenuator output impedances.

r_2 = Reflection coefficient corresponding to S_2

When reading the reference power level with the equipment arranged as shown in Figure 2b, an additional uncertainty in measurement occurs when the generator and load are mismatched;

$$E_R = \left|r_R\right|^2 \tag{A-13}$$

where

$$r_R = \frac{S_R - 1}{S_R + 1} \tag{A-14}$$

$$\frac{S_G}{S_L} \leq S_R \leq S_G S_L \tag{A-15}$$

S_R = Effective SWR of the mismatched generator and load

R = Reflection coefficient corresponding to S_R

The combined effect E of the uncertainties described above is equal to:

$$E = \frac{E_1 E_2}{E_R} \tag{A-16}$$

or, when all terms are expressed in db,

$$E' = E'_1 + E'_2 - E'_R \tag{A-17}$$

where

$$E'_1 = 10 \log \left(\frac{1}{1 - E_1} \right) \quad \text{etc.} \tag{A-18}$$

A calculation of the uncertainty of a measurement is shown in the following example. Assuming:

$S_G = 1.3$

$S_L = 1.16$

$S_i = S_o = 1.2$

From equations 6 and 7,

$0.039 \leq r_1 \leq 0.219$

$r_i = 0.0909$

Then, from equation 9,

$-0.006 \leq E_1 \leq 0.040$

The corresponding dB values can be computed from equation A-18.

$0.027 \leq E'_1 \leq 0.178$ dB

Similarly, from equations A-10, A-11, A-12, and A-18

$-0.036 \leq E'_2 \leq 0.085$ dB

and from equations A-13, A-14, A-15, and A-18

$$0.013 \leq E'_R \leq 0.191 \text{ dB}$$

The extreme values of the uncertainty E' can be found by combining the above values in accordance with equation A-17.

$E' = 0.178 + 0.085 - 0.013 = 0.250$ dB (maximum positive)

$E' = -0.027 - 0.036 - 0.043 = -0.106$ dB (maximum negative)

3. REDUCTION OF MISMATCH ERRORS

The use of a matched attenuator between a mismatched generator or load and the measurement circuit will reduce the SWR of these components. The improved SWR is related to the original SWR as follows:

$$S = \frac{A(S_G + 1) + (S_G - 1)}{A(S_G + 1) - (S_G - 1)} \qquad \text{(A-19)}$$

where S = Improved SWR

S_G = Original SWR of the generator (or load)

A = Attenuator loss $\left(\frac{P_{in}}{P_{out}}\right)$

The attenuator should be placed immediately adjacent to the unknown attenuator in order to reduce reflections from all possible sources in the "generator" or "load" sections of the measurement system.

The following example illustrates the improvement obtained in the SWR of a signal generator by the use of a perfectly matched 6-dB attenuator.

If $S_G = 3$

and $A = 4$

then, from equation A-19:

$S = 1.3$

Ferrite isolators used in place of the matched attenuators will also provide an improved SWR and, because of their low insertion loss, there will be very little reduction in the attenuation measurement range. The main disadvantages of the ferrite isolators are their high cost and limited frequency range.

An alternative method of reducing the mismatch of the generator and load sections of the measurement system is to use a tuner on each side of the unknown attenuator as shown in Figure A-3.

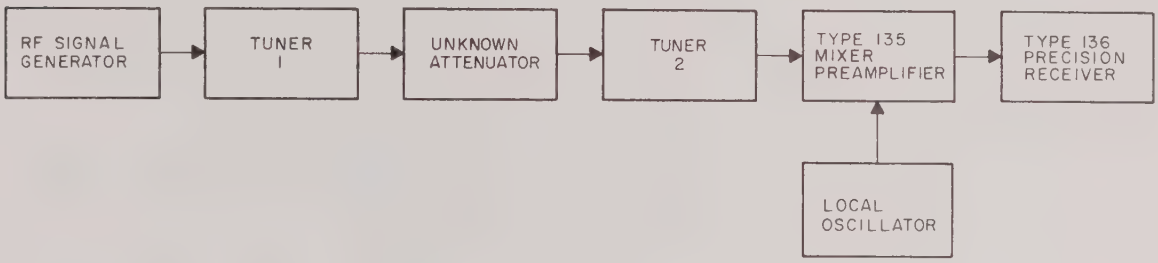


FIGURE A-3. USE OF TUNERS IN ATTENUATION MEASUREMENT

To adjust tuner 2, a slotted line can be inserted in place of the unknown attenuator. The local oscillator should be set to the desired operating frequency and its level adjusted for proper crystal current in the mixer. The RF signal generator should be modulated by 1 kHz to provide a signal for the SWR indicator used with the slotted line. Tuner 2 should then be adjusted until the indicated SWR is reduced to the desired level. An SWR of 1.02 should be obtainable.

Tuner 1 can be adjusted in a similar manner by turning off the RF signal generator, disconnecting tuner 2 from the slotted line, and feeding the output of a second signal generator into this port of the slotted line. The second generator must be tuned to the same operating frequency as the first generator and must be modulated by 1 kHz. If a ferrite isolator is used between the signal generator and tuner 1, the signal generator can be disconnected from the isolator and used as the signal source for the adjustment of

tuner 1. In addition, the use of the isolator makes it possible to change the setting of the signal generator output attenuator without readjusting the tuner.

4. SYSTEM NONLINEARITY ERRORS

In any IF-substitution measurement of RF attenuation, the accuracy is dependent upon the linearity of the circuit elements between the unknown attenuator and the precision IF attenuator. The combination of the Type 135 mixer and the Type 136 high-power IF preamplifier has been designed to provide a very wide linear range.

The linearity of the system can be checked by making a series of measurements of a fixed RF attenuator over a range of input signal levels. The procedure is as follows:

1. Measure the attenuation of a fixed RF attenuator of approximately 20 dB, using an RF signal level somewhere near the center of the linear operating range of the system.
2. Adjust the RF signal generator output to a slightly higher level.
3. Using the same reference setting of the precision attenuator as was used in step 1, adjust the receiver gain control to obtain the same output reference reading as was used in step 1.
4. Measure the unknown attenuator at this new signal level.
5. Remeasure the unknown attenuator at other signal levels over the range of interest.

Readings taken in the linear range of the system will be identical. As the nonlinear areas are approached at each end of the range, lower attenuation readings will be obtained. The difference between these reduced readings and the correct attenuation, measured in the linear range, is a measure of the system error caused by the nonlinearity of the mixer-preamplifier at the signal level of the measurement.

5. SIGNAL LEAKAGE ERRORS

When attenuation measurements are made over a large range, errors may occur as a result of signal leakage. During an attenuation measurement, any leakage of the signal around either the RF attenuator or the precision IF

attenuator will cause an error. Figure A-4 shows a leakage path around an unknow attenuator.

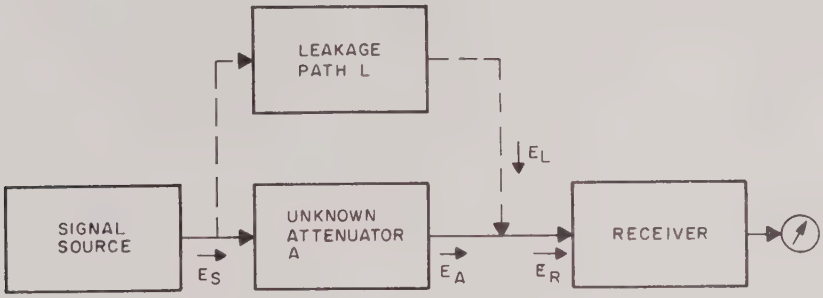


FIGURE A-4. LEAKAGE PATH AROUND AN UNKNOWN ATTENUATOR

The effect of the signal transmitted through the loosely coupled leakage path can be calculated as follows:

$$A = \frac{E_S}{E_A}$$

$$L = \frac{E_S}{E_L}$$

where A = Loss of the unknown attenuator

L = Loss of the leakage path

E_S = Source voltage

E_A = Output voltage of the attenuator

E_L = Output voltage of the leakage path

Since

$$E_R = E_A \pm E_L$$

$$E_R = \frac{E_S}{A} \pm \frac{E_S}{L}$$

and

$$E_R = \frac{E_S}{A}\left(1 \pm \frac{A}{L}\right)$$

Since the voltages E_A and E_L are vector quantities whose relative phase is unpredictable, the quantity $\frac{A}{L}$ represents a maximum uncertainty in the measurement of the unknown attenuation A. The quantities A and L are expressed here as voltage ratios and, therefore, the uncertainty E may be expressed in decibels as

$$E = 20 \log \left(1 \pm \frac{A}{L}\right)$$

As an example, if the signal transmitted through the leakage path is 20 db lower than that through the unknown attenuator (A/L = 0.1), then the uncertainty of measurement is within the limits of ±0.8 dB.

The actual leakage in a measurement system can be determined by removing the unknown attenuation, terminating both ports of the measurement system, and measuring the decrease in signal level at the receiver as shown in Figure A-5.

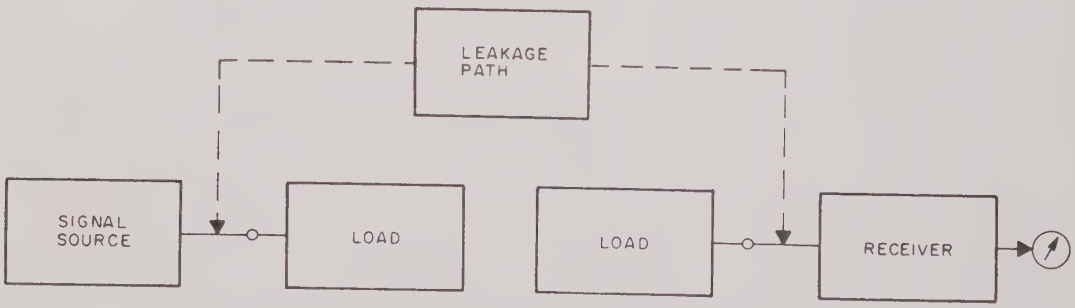


FIGURE A-5. MEASUREMENT OF LEAKAGE PATH

Careful attention to the selection and arrangement of the component parts of the measurement system can reduce leakage. For instance, coaxial connectors must be in good condition and be properly fitted to the cables, waveguide flanges must be in good condition and properly mated, and the signal source must be adequately shielded and its power line well filtered.

APPENDIX B

METHODS OF NOISE TEMPERATURE MEASUREMENT

1. NOISE TEMPERATURE THEORY

A discussion of the theory of noise temperature measurement requires first a definition of the terms and quantities involved. This section is devoted to a brief development of the basic relations between noise power, effective input noise temperature, and noise figure. Further information and more detailed derivations can be obtained by consulting the references listed at the end of this Appendix.

a. NOISE POWER

Throughout this section, reference is made to noise power originating from various sources. The definitions and measurements are in terms of the equivalent thermal noise power, that is, the noise generated as a result of the thermally agitated, random motion of electrons in a conductor. This is sometimes referred to as Johnson noise. Nyquist's theorem defines the relation between noise power and temperature. The result is given in equation B-1.

$$N = KT \tag{B-1}$$

where

N = noise power per unit bandwidth which would be delivered to a conjugately matched load,

K = Boltzmann's constant (1.38×10^{-23} joules/°K),

T = temperature in degrees Kelvin.

Equation B-1 states that the noise power per unit bandwidth available at the terminals of a resistor is directly proportional to the absolute temperature. Note that N is independent of the resistance value and the type of resistor.

b. EFFECTIVE INPUT NOISE TEMPERATURE (T_e)

The available noise power at the output of a network with multiple input ports and a single output port can be given as:

$$N_o = N'_{i1}G_1 + N'_{i2}G_2 + N'_{i3}G_3 \text{ ---------} + N'_{in}G_n \quad \text{(B-2)}$$

where

N'_{in} = noise power available from all sources at the nth input port,

G_n = ratio of the signal power delivered to the load to the signal power available at the nth input port (transducer gain).

The term N'_{in} can be expressed as the sum of two components:

$$N'_{in} = N_{in} + N_e \quad \text{(B-3)}$$

The term N_e represents the internal noise of the network. Note that this quantity is assigned simultaneously to all input ports. A noise temperature (T_{in}) can be assigned to each of these components in accordance with equation B-1;

$$N'_{in} = K\,(T_{in} + T_e) \quad \text{(B-4)}$$

and

$$N_o = K\left[(T_{i1} + T_e)\,G_1 + (T_{i2} + T_e)\,G_2 \text{----} + (T_{in} + T_e)\,G_n\right] \quad \text{(B-5)}$$

The term T_e is called the effective input noise temperature of the network, and it is a measure of its internal noisiness. If the terminations at all inport ports are at the same temperature, then

$$N_o = K(T_i + T_e) \sum_{n=1}^{n} G_n \quad \text{(B-6)}$$

c. OPERATING NOISE TEMPERATURE (T_{op})

As shown above, effective input noise temperature (T_e) is a measure of the internal noisiness of a network. In contrast, operating noise

temperature (T_{op}) is a measure of the overall noise performance of a receiving system in its actual operating environment. This quantity can be defined for a system, where one input port is designated the primary signal channel, in terms of the total noise output power of the system;

$$N_o = K T_{op} G_s \tag{B-7}$$

where

G_s = gain of the primary signal channel.

Operating noise temperature can be related to effective input noise temperature by combining equations B-6 and B-7;

$$T_{op} = (T_i + T_e) \sum_{n=1}^{n} \frac{G_n}{G_s} \tag{B-8}$$

If the system has only one channel,

$$T_{op} = (T_i + T_e) \tag{B-9}$$

One multiple-channel system of particular interest is the heterodyne receiver. Although there may be only one physical input port, there are two possible frequency transformations and, hence, two distinct channels. If one transformation is designated the signal channel and the other, the image, then:

$$T_{op} = (T_i + T_e)\left(1 + \frac{G_{im}}{G_{sig}}\right) \tag{B-10}$$

d. NOISE FIGURE

Noise figure is probably the most commonly used measure of amplifier noise performance. It can be expressed as the ratio of the noise power output of a network to the noise power output of an ideal noiseless network of otherwise identical characteristics when the input termination is at 290 K (as defined by the IEEE Standards on Electron Tubes). This is expressed mathematically in equation B-11.

$$F = \frac{N_o}{G_{sig} N_i} \tag{B-11}$$

Noise figure is also sometimes defined as the ratio of the input signal-to-noise ratio to the output signal-to-noise ratio when the input termination is at 290°K. This is expressed in equation B-12.

$$F = \frac{S_i/N_i}{S_o/N_o} \tag{B-12}$$

It can be seen that these two expressions are equivalent, if it is noted that

$$\frac{S_i}{S_o} = \frac{1}{G_{sig}} \tag{B-13}$$

Note also that noise figure is defined only for a two-port transducer. For the special case of a heterodyne system, the term $G_s N_i$ applies only to the principal frequency transformation and does not include spurious contributions such as those from an unused image-frequency or an unused idler-frequency transformation.

Noise figure can be related to effective input noise temperature by combining equations B-6 and B-11 and noting the restrictions cited above;

$$F = \left(\frac{T_o + T_e}{T_o}\right)\left(1 + \frac{G_{im}}{G_{sig}}\right) \tag{B-14}$$

where T_o = the reference temperature, 290°K

For a single-channel system, $G_{im} = 0$

and

$$F = \frac{T_e}{290} + 1 \tag{B-15}$$

The rest of this appendix assumes that the system under test is a single-channel, two-port system; however, if the system under test is a heterodyne system, the results should be adjusted in accordance with the second parenthetical term in equation B-14.

2. NOISE-TEMPERATURE MEASUREMENT THEORY

a. Y FACTOR

Most methods used to measure effective input noise temperature and noise figure do so by determining the change in system noise output power for a known change in input noise power. The input to the network under test is first connected to a termination at some temperature T_1. An output reference level that is indicative of the noise power out of the system (N_{o1}) is then noted. Substituting the known value of T_1 for T_i in equation B-6, the expression for N_{o1} can be written:

$$N_{o1} = K (T_1 + T_e) G \tag{B-16}$$

The network input termination is then raised to a temperature T_2 by physically changing terminations, energizing a noise lamp, etc. The output indication will increase. The noise output power under this condition can be written:

$$N_{o2} = K (T_2 + T_e) G \tag{B-17}$$

An accurately known amount of attenuation is then inserted between the network output and the output level indicator. This attenuation is adjusted so that the output level is the same as the original reference level. The required amount of attenuation is equal to the ratio of N_{o2} to N_{o1}; this ratio is called the Y-factor and can be expressed as

$$Y = \frac{N_{o2}}{N_{o1}} \tag{B-18}$$

b. EFFECTIVE INPUT NOISE TEMPERATURE

Once the Y factor has been measured, T_e can be computed by substituting equations B-16 and B-17 into B-18:

$$Y = \frac{T_2 + T_e}{T_1 + T_e} \tag{B-19}$$

Solving equation B-19 for T_e:

$$T_e = \frac{T_2 - YT_1}{Y - 1} \tag{B-20}$$

Temperature T_2 is a function of the type of noise generator used, and T_1 is generally assumed equal to room temperature for gas-discharge and temperature-limited diode noise generators. Thermal-noise generators, such as the AIL Types 07002 and 07004 hot-cold standard noise generators provide a cold-termination temperature T_1 near that of liquid nitrogen. Y factor is usually measured with a variable, calibrated, waveguide-beyond-cutoff attenuator in the intermediate frequency section of the measurement setup. This attenuator is generally calibrated in db, and the result must be converted to a power ratio prior to substitution into equation B-20.

c. NOISE FIGURE

The noise figure of the unit under test can be determined by substituting equation B-20 into equation B-15. The result is:

$$F = \frac{\frac{T_2}{290} - Y\frac{T_1}{290}}{Y - 1} + 1 \tag{B-21}$$

This result does not account for the possible presence of an image. If the system does exhibit a significant response at an unused image frequency, then equation B-21 must be modified by multiplying by the parenthetical factor $(1 + G_{im}/G_{sig})$, as indicated in equation B-14.

When gas-discharge or temperature-limited diode noise generators are used, T_1 is quite often assumed to be equal to the reference temperature T_o (290°K). Under this condition equation B-21 reduces to:

$$F = \frac{\frac{T_2}{T_o} - 1}{Y - 1} \qquad \text{(B-22)}$$

This relation should be used with caution, particularly when the system under test is a very low noise device (see part 3a of this appendix).

The quantity in the numerator of equation B-22 is generally specified as a measure of the output capability of a noise generator. It is called the relative excess noise temperature or excess noise ratio, and it is most often expressed in dB, as noted below.

$$T_{ex}(dB) = 10 \text{ Log } \left(\frac{T_2}{T_o} - 1 \right) \qquad \text{(B-23)}$$

3. ACCURACY CONSIDERATIONS

a. TERMINATION TEMPERATURE

Equation B-22, which assumes a cold-termination temperature equal to 290°K, is almost universally used to calculate noise figure when gas-discharge or temperature-limited diode noise generators are employed. It forms the basis for the meter scaling of all automatic measurement instruments and many of the computational aids in use today. However, the cold-termination temperature of the noise generator types mentioned can differ quite significantly from 290°K for a variety of reasons; for instance, the DC power dissipation in an argon gas discharge lamp (typically about 20 watts) could be enough to heat the termination to several degrees above room temperature. In fact, actual room temperature is usually several degrees above 290°K (about 62° F).

The extent of the error caused by the use of equation B-22 can be seen by referring to Figure B-1. This plot gives the difference between the calculated noise figure obtained when using equation B-22 and when using the exact relation, equation B-21 (all quantities expressed in dB). In Figure B-1, F_m is the measured noise figure, that is, that which would be calculated from equation B-22; δ is the correction to be applied to F_m to obtain the true noise figure F_a, that which would be calculated from equation B-21.

b. SECOND-STAGE NOISE

This is the name given to the effects of the second or following elements of a cascaded amplification system. In general, if the gain of the first stage is high, these effects will be small; however, if the second-stage noise figure is high and the first-stage gain is low, the contribution of the second stage to the overall measured noise temperature or noise figure can be significant.

A measurement system consisting of the device under test followed by a supplementary amplifier or test receiver can be considered a cascade. Consequently, it may be necessary to consider the noise performance of the test receiver and correct the measured result for its contribution.

Second-stage effects can be evaluated as follows: The noise-power output per unit bandwidth of the device under test is given by equation B-6 (ignoring multiple responses):

$$N_{o1} = K(T_i + T_{e1})\, G_1 \tag{B-24}$$

where the subscripts (1) refer to the first stage. Noting that,

$$T_{e1} = (F_1 - 1)\, T_o \tag{B-25}$$

and assuming that $T_i = T_o$,

$$N_{o1} = KG_1F_1T_o \tag{B-26}$$

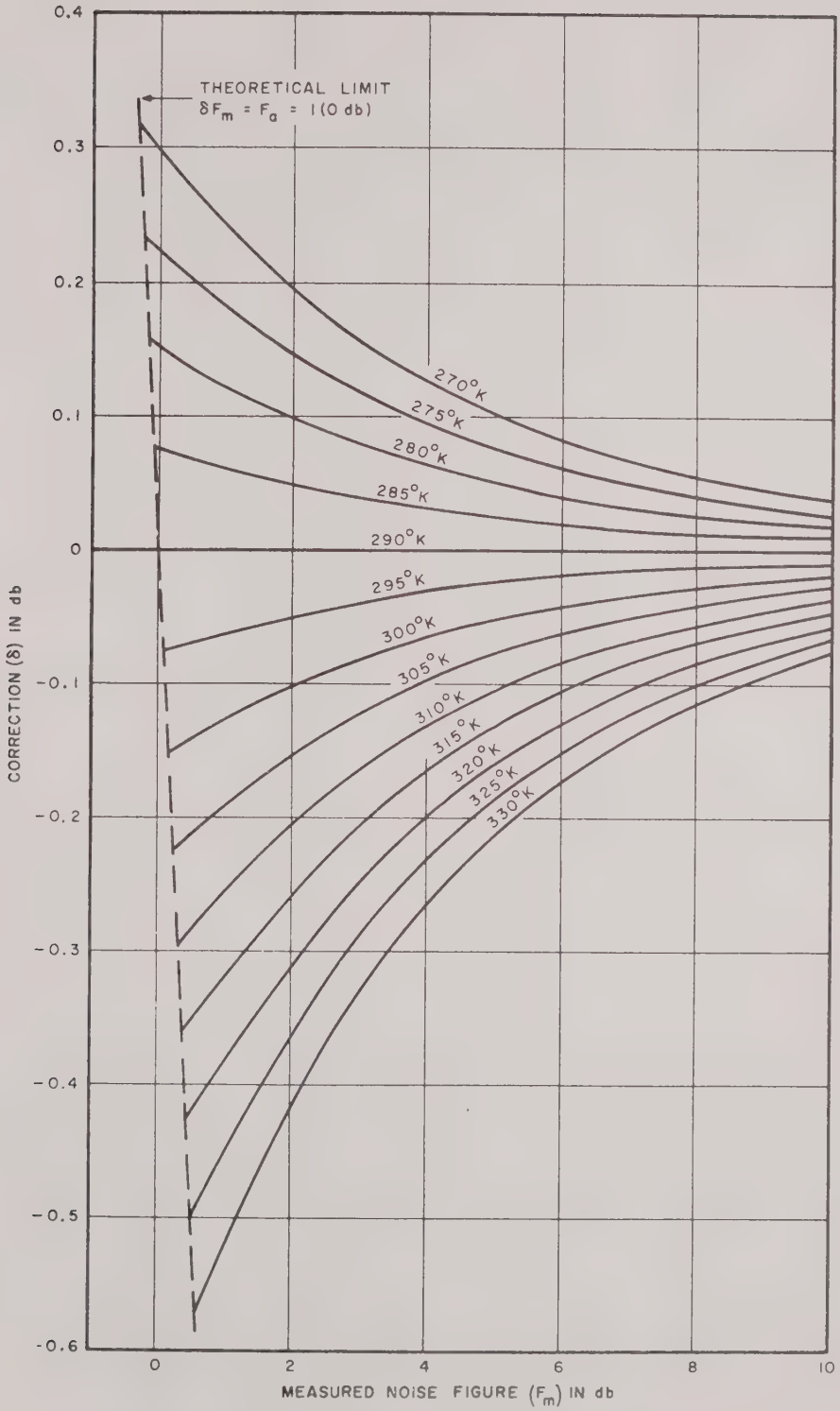


FIGURE B-1. CORRECTION FOR $T_1 \neq T_0$ (TERMINATION TEMPERATURE)

The noise-power output of the overall system would be the output of the first stage plus the internal noise of the second stage, referred to its input, amplified by the gain of the second stage. The internal noise of the second stage, referred to its input, is simply KT_{e2} or $K(F_2 - 1)\, T_o$. Therefore,

$$N_{o2} = G_2 \left[N_{o1} + K(F_2 - 1)T_o \right] \tag{B-27}$$

Substituting equation B-26 into this,

$$N_{o2} = G_2 K T_o \left[F_1 G_1 + (F_2 - 1) \right] \tag{B-28}$$

The total noise output N_{o2} of the system can, by definition, be written in terms of an overall or system noise figure:

$$N_{o2} = K G_1 G_2 F_{1-2} T_o \tag{B-29}$$

where, F_{1-2} = overall system noise figure.

Equating B-28 and B29

$$K G_1 G_2 F_{1-2} T_o = G_2 K T_o \left[F_1 G_1 + (F_2 - 1) \right] \tag{B-30}$$

and

$$F_{1-2} = F_1 + \frac{F_2 - 1}{G_1} \tag{B-31}$$

The quantity $(F_2 - 1/G_1)$ is the contribution of the second stage to the overall or measured noise figure. It can be seen, then, that if the second-stage noise figure is high and/or the first-stage gain is low, this contribution could be significant. Figure B-2 is a nomograph of equation B-31, and it can be used to determine the extent of these effects. The value of F_{1-2} is the noise figure that would be measured for the system. ϵdB is the correction to be added algebraically to F_{1-2} (in dB) to obtain the first stage noise figure F_1.

c. BANDWIDTH EFFECTS

The total noise power available in an amplifying or receiving system is actually characterized by its noise temperature or noise figure averaged

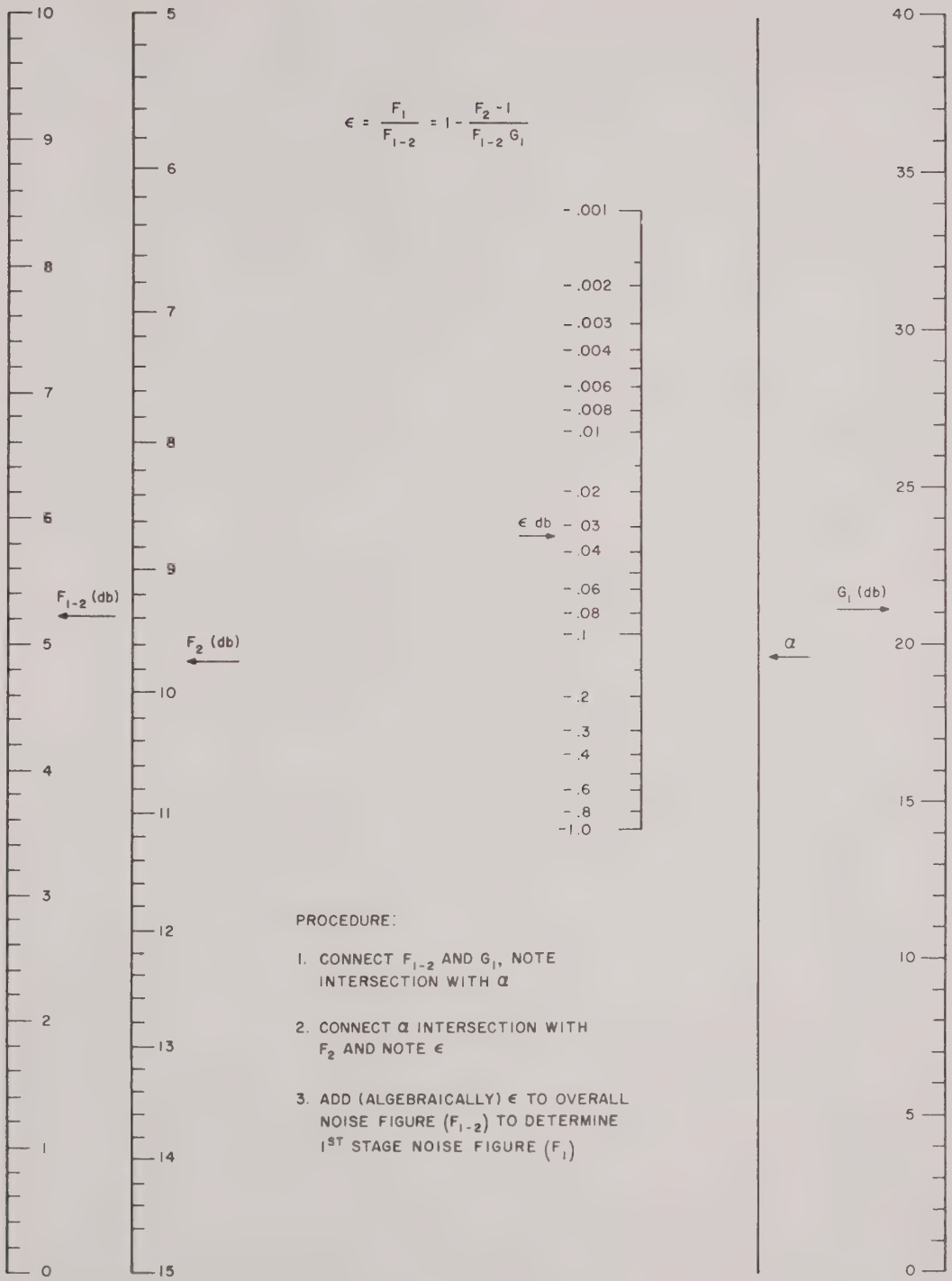

$\epsilon = \frac{F_1}{F_{1-2}} = 1 - \frac{F_2 - 1}{F_{1-2} G_1}$
F_{1-2} (db)
F_2 (db)
ϵ db
G_1 (db)
α
PROCEDURE:
1. CONNECT F_{1-2} AND G_1, NOTE INTERSECTION WITH α
2. CONNECT α INTERSECTION WITH F_2 AND NOTE ϵ
3. ADD (ALGEBRAICALLY) ϵ TO OVERALL NOISE FIGURE (F_{1-2}) TO DETERMINE 1ST STAGE NOISE FIGURE (F_1)

FIGURE B-2. NOMOGRAPH, CORRECTION FOR SECOND-STAGE NOISE FIGURE

over its bandwidth. Since a signal must compete with this total noise rather than noise at a single frequency, it is these average quantities that are of major interest to the system designer.

If the bandwidth of the measuring system is slightly greater than that of the system under test, then the procedures indicated will yield average noise figure or noise temperature directly. If, however, the measurement bandwidth is narrow with respect to the system bandwidth, then the quantity measured approximates what is called spot noise figure or temperature. An accurate determination of the noise performance of the system then requires several measurements averaged over the band.

4. REFERENCES

a. Haus, et. al., IRE Standards on Electron Tubes: Definitions of Terms, 1962* (62 IRE 7.S2) Proceedings of the IEEE, 434-435, March 1963.

b. Haus, et. al., "Description of the Noise Performance of Amplifiers and Receiving Systems," Proceedings of the IEEE, 436-442, March 1963.

c. M. Lebenbaum, "Measurement of Noise Figure," Handbook of Electronic Measurements, Vol. II, Chap. XI, p 1-51, Polytechnic Institute of Brooklyn, 1956.

APPENDIX C

AUXILIARY EQUIPMENT

TABLE C-1A
MIXERS, COAXIAL

Frequency Range (MHz)	AIL Part Number
10-1000	13508
1000-2000	13504
2000-4000	13505
4000-8000	13506
7000-11000	13507

TABLE C-1B
MIXERS, WAVEGUIDE

Frequency Range (GHz)	AIL Part Number
3.7 to 4.2	13522
4.4 to 5.0	13523
5.4 to 5.9	13524
5.9 to 6.5	13525
6.5 to 7.5	13526
7.5 to 8.5	13527
8.5 to 9.6	13528
8.8 to 10.25	13529
10.0 to 12.4	13531
12.4 to 14.0	13532
13.5 to 15.6	13533
15.0 to 17.0	13534
23.0 to 25.0	13538
34.0 to 36.0	13539
17.0 to 19.7	13541
25.0 to 29.0	13542
29.0 to 34.0	13543
36.0 to 40.0	13544
19.7 to 23.0	13545
8.2 to 12.4	13546
12.4 to 18.0	13547

TABLE C-2
NOISE GENERATORS

Frequency Range	Type	Part No.
0 - 6.0 GHz	Hot/cold standard	07004
10 - 250 MHz	Diode	07006
0.2 - 2.6 GHz	Coaxial	07010
2.0 - 5.0 GHz	Coaxial	07012
2.6 - 3.95 GHz	Waveguide with termination	07048T
3.95 - 5.85 GHz	Waveguide with termination	07049T
5.85 - 8.2 GHz	Waveguide with termination	07050T
7.05 - 10.0 GHz	Waveguide with termination	07051T
8.2 - 12.4 GHz	Waveguide with termination	07052T
12.4 - 18.0 GHz	Waveguide with termination	07053T
18.0 - 26.5 GHz	Waveguide with termination	07091T
26.5 - 40.0 GHz	Waveguide	07096

TABLE C-3
NOISE GENERATOR POWER SUPPLIES

Unit	Part No.	Use
Power Supply	7111	Gas-discharge noise generator
Power Supply	7112	Diode noise generator

TABLE C-4
TEST SET

Unit	Type	Use
Microwave Crystal Test Set	391	Checks crystals in coaxial and waveguide mixers

TABLE C-5
SIGNAL SOURCE

Unit	Type	Use
High-Power Signal Source	125	Used as local oscillator from 200 to 3000 MHz
High-Power Signal Source	126	Used as local oscillator from 2 to 8 GHz

APPENDIX D

APPLICATION FOR TYPE 13635 FREQUENCY CONVERTER

Performance information on the conversion efficiency and harmonic responses of the 13635 converter is provided below.

The AIL Type 13635 frequency converter increases the usable frequency range of the AIL Type 13610 30 MHz receiver. The converter physically mates to the 13630 low-noise preamplifier or the 13650 large dynamic range preamplifier to provide frequency coverage from 35 to 500 MHz. A block diagram describing use of the converter with the 136 receiver is shown in Figure D-1.

The basic tuning range of the local oscillator is from 60 to 120 MHz which enables fundamental mixing of RF signals over the range from 35 to 150 MHz. In a portion of this RF signal band there will also be a response due to the second harmonic of the LO. Figure D-2 shows the responses that will be obtained from the fundamental and harmonics of the LO. Typical conversion loss corresponding to the LO harmonic number is also indicated.

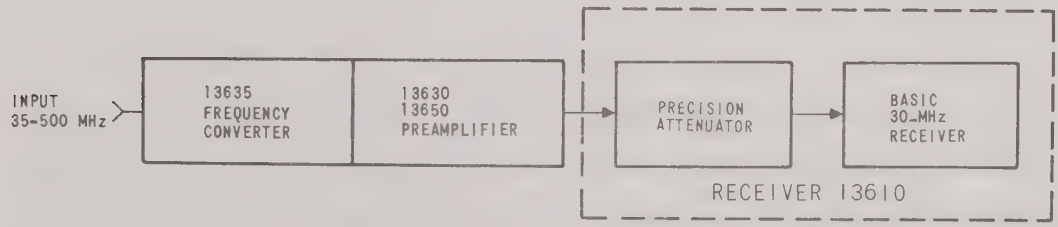


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FIGURE D-1. TYPE 13635 FREQUENCY CONVERTER USED WITH TYPE 136 RECEIVER

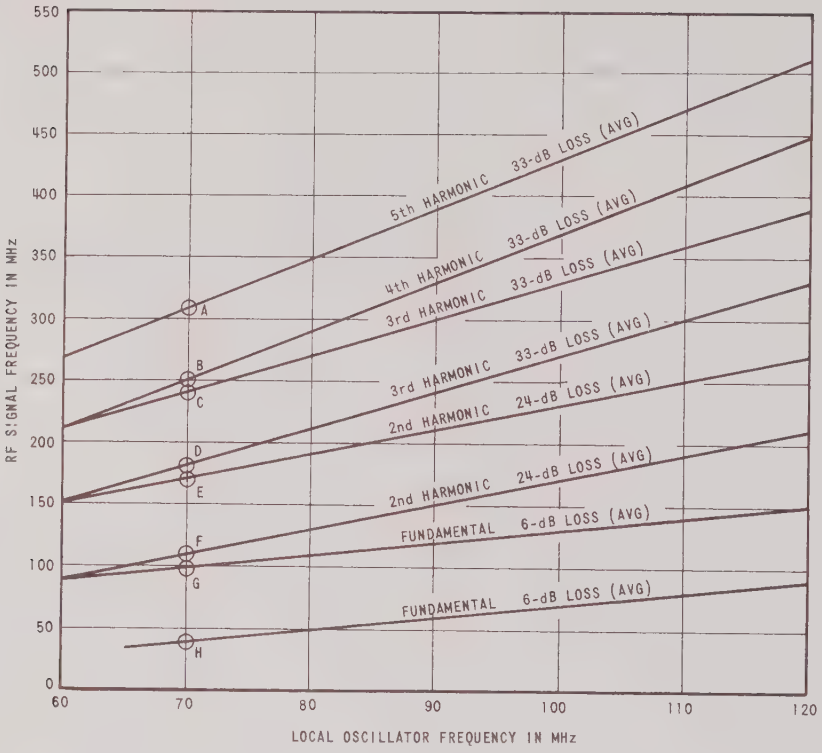

FIGURE D-2. CONVERSION LOSS AND LOCAL OSCILLATOR HARMONIC RESPONSES OF TYPE 13635 FREQUENCY CONVERTER

Figure D-2 is useful for predicting the multiple responses that will be obtained for a fixed LO frequency. If a vertical line is drawn to indicate the LO frequency, the intersections of this line and the lines drawn in the figure will indicate the responses that will be obtained. Similarly, if a horizontal line is drawn to indicate the signal frequency, the intersections of this line will indicate the local oscillator frequencies at which a response can be obtained. An angle of multiple RF responses is given in the figure. At a fixed LO frequency of 20 MHz, eight responses will be obtained and are indicated by the lettered circles.

APPENDIX E

APPLICATION FOR TYPE 136 PREAMPLIFIERS

The two preamplifiers which are available for use with the Type 136 Precision Receiver provide for a wide range of applications. In selecting an amplifier for a specific application, the following guidelines should be followed:

1. In making RF attenuation measurements, a wider dynamic range can always be obtained with the Type 13650 High-Power Preamplifier.
2. The measurement of the variation of an RF signal over a wide dynamic range, such as in antenna pattern analysis, also requires the use of the Type 13650 Preamplifier.
3. The selection of a preamplifier for use in making noise figure measurements depends on several factors as illustrated in the following examples. However, it is important to recognize that in all cases the accuracy of the measurement is not affected by the noise figure of that portion of the test equipment including the precision attenuator and the IF amplifier following it. A high noise level at this point reduces the sensitivity of the output indicator but has no direct effect on the accuracy of the measured noise figure.

A. PROBLEM 1

An RF amplifier intended for operation over the telemetry band from 2.2 to 2.3 GHz has a gain (G) of 20 dB, a noise figure (F) of 2 dB, and a bandwidth (B) of 100 MHz. The test equipment is set up as shown in the following block diagram (Figure E-1).

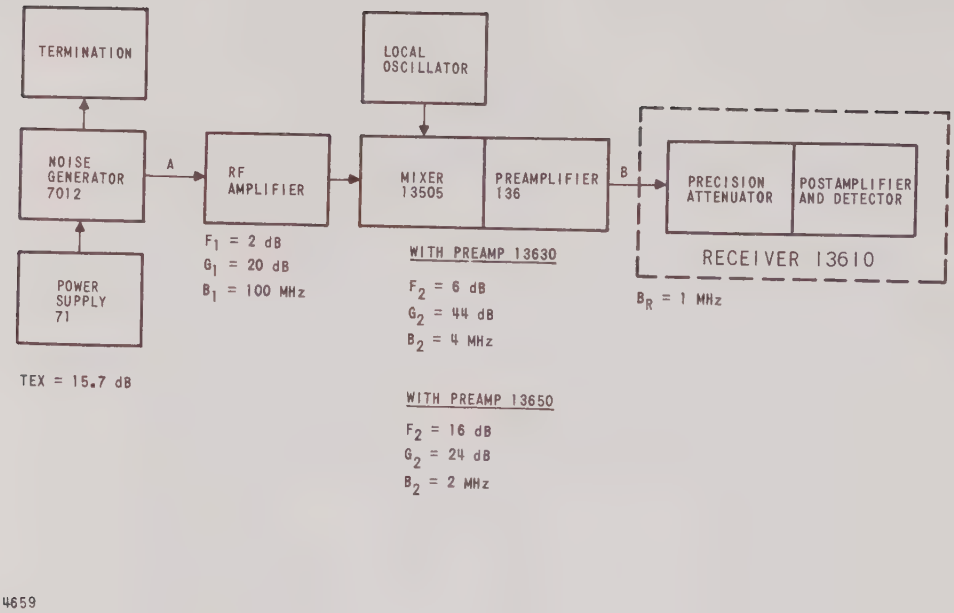

FIGURE E-1. TEST SETUP

If it is assumed that the RF amplifier has equal gain at the two frequencies located 30 MHz on either side of the local oscillator frequency, then the noise figure of the mixer-preamplifier, F_2, to be used in this calculation is the double-sideband noise figure. Other cases are covered in the "Guide to Accurate Noise Measurement" by Robert L. Sleven, published in the July 1964 issue of Microwaves.

The measured overall noise figure, F_{12}, is:

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1}$$

$$= 1.59 + \frac{4.0 - 1}{100} = 1.62 \text{ or } 2.1 \text{ dB}$$

Therefore, the contribution of this mixer-preamplifier to the overall noise figure is 0.1 dB and a correction can be made for this amount.

In order to determine the power output requirements of the preamplifier, a calculation of the output noise power can be made as follows:

Noise power at the input of a perfect receiver		
Bandwidth correction (B_2 = 4 MHz)	6.0 dB	-114 dBm/MHz
Noise figure correction	2.1	
Noise on/Noise off (Y-factor)	13.8	
		+ 21.9
Maximum rms noise level at point A		- 92.1 dBm
RF amplifier gain	+20 dB	
Mixer loss	- 6	
Preamplifier gain	+50	
Total gain		64 dB
Maximum rms noise level at point B		- 28.1 dBm

In order to obtain linear amplification of a specific rms noise power, it is necessary to provide a linear range approximately 10 dB higher than that required for a sine wave signal of the same power. Therefore, the peak noise power that must be considered in this example is -18.1 dBm.

Since the output of the 13630 is linear to -10 dBm, it could be used in this application.

1. ALTERNATE SOLUTION TO PROBLEM 1

If the Type 13650 High-Power Preamplifier were used in making the same measurement, then the measured overall noise figure would be:

$$F_{12} = 1.59 + \frac{63.1 - 1}{100} = 1.98 \text{ or } 2.97 \text{ dB}$$

The contribution of this mixer-preamplifier to the overall noise figure would be 0.97 dB and again a correction of this amount should be made.

Noise power at the input of a perfect receiver		-114 dBm/MHz
Bandwidth correction (B_2 = 2 MHz)	+ 3.0 dB	
Noise figure correction	+ 3.0	
Noise on/Noise off (Y-factor)	+13.0	
		+ 19
Maximum noise level at point A		- 95 dBm
RF amp gain	+20 dB	
Mixer loss	- 6	
Preamplifier gain	+30	
Total gain		44 dB
Maximum rms noise level at point B		- 51 dBm
Peak noise power at point B		- 41 dBm

The 13650 preamplifier has a linear output capability of +15 dBm and is well applied in this application.

2. ANALYSIS

In this application, either the 13630 or the 13650 preamplifier could be used. The low-noise preamplifier will not require as large a correction for second-stage noise contribution but may not have enough linear dynamic range if the bandwidth of the preamplifier is wider or the gain of the RF amplifier or preamplifier is higher. The high-power preamplifier will require a larger noise figure correction but will tolerate a considerable increase in the gain of the preamplifier or RF amplifier.

B. PROBLEM 2

Figure E-2 shows the test setup for the measurement of a receiver system including a frequency converter.

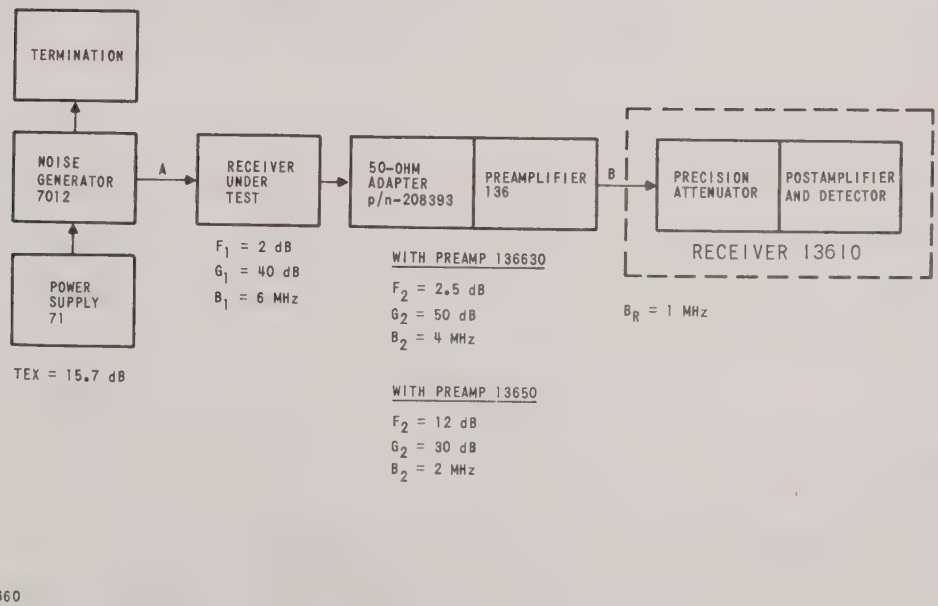

FIGURE E-2. TEST SETUP FOR MEASUREMENT OF A RECEIVER SYSTEM INCLUDING FREQUENCY CONVERTER

In this case, it is assumed that the receiver under test contains the low-noise amplifier, mixer, filter, isolator, and IF amplifier necessary to provide a single-frequency response at 2250 MHz with a gain of 40 dB, a noise figure of 2 dB, an output signal at 30 MHz, and an overall bandwidth of 6 MHz.

The measured overall noise figure when using the low-noise preamplifier is:

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1}$$

$$= 1.59 + \frac{1.78 - 1}{10,000} = 1.59 + 0.000078 = 1.59 = 2 \text{ dB}$$

The contribution of the low-noise preamplifier to the overall noise figure is insignificant. The power output requirements for the preamplifier can be determined as follows:

Noise power at the input of a perfect receiver		-114 dBm/MHz
Bandwidth correction (B_2 = 4 MHz)	6.0 dB	
Noise figure correction	2.0	
Noise on/Noise off (Y-factor)	13.9	
		+ 21.9
Maximum rms noise level at point A		- 92.1 dBm
Receiver gain	40 dB	
Preamplifier gain	50	
Peak noise/rms noise	10	
		+100
Peak noise power at point B		+ 7.9 dBm

Since the Type 13630 Preamplifier is only capable of linear amplification up to a power output level of -10 dBm, it would be completely unsuited for this application.

If the Type 13650 High-Power Preamplifier is used in this application, the overall noise figure is:

$$F_{12} = 1.59 + \frac{15.8 - 1}{10,000} = 1.59 + 0.0015 = 1.59 = 2 \text{ dB}$$

Again the noise contribution of the preamplifier is negligible. The power output requirement is computed as follows:

Noise power at the input of a perfect receiver		-114 dBm/MHz
Bandwidth correction (B_2 = 2 MHz)	3.0 dB	
Noise figure correction	2.0	
Noise on/Noise off (Y-factor)	13.9	
		+ 18.9 dB
Maximum rms noise level at point A		- 95.1 dBm
Receiver gain	40 dB	
Preamplifier gain	30	
Peak noise/rms noise	10	
		80.0
Peak noise power at point B		- 15.1 dBm

Since the Type 13650 High-Power Preamplifier is capable of linear amplification up to power levels of +15 dBm, a margin of 30 dB is available.

ANALYSIS

In this application, the measurement can be made only with the Type 13650 High-Power Preamplifier and there is no correction required for second-stage noise figure. Again, it is important to realize that it is not necessary for this preamplifier to have enough gain to overcome the noise figure of the combination of the precision attenuator and the IF post-amplifier in the precision receiver used for this test.